ABSTRACT

Title of Thesis:	CONSIDERING THE ROLE OF PHYSIOLOGICAL REWARDS IN THE RELATIONSHIP BETWEEN IMPULSIVITY AND DECISION MAKING
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Individual levels of impulsivity and anticipated physiological rewards (i.e., thrill) associated with offending have both been recognized as important aspects of the criminal decision-making calculus. However, the extant literature does not have a clear understanding of the dynamics between the two constructs and crime, specifically how physiological rewards matter in the impulsivity-offending relationship. Using the dual-process framework of decision making, this thesis explores first whether impulsivity influence offending indirectly through perceived physiological rewards, and second whether individuals are differentially susceptible to physiological rewards according to their levels of impulsivity (i.e. moderation). These hypotheses are tested using two waves of the Pathways to Desistance study. The results provide support that physiological rewards partially mediate the relationship between impulsivity and offending, yet there is no statistically significant moderating relationship.

CONSIDERING THE ROLE OF PHYSIOLOGICAL REWARDS IN THE RELATIONSHIP BETWEEN IMPULSIVITY AND DECISION MAKING

by

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Dedication

This thesis is dedicated to my friends and family, specifically my late grandparents.

All of this would not have been possible without their continuous love and support.

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Chapter 1: Introduction

"Rewards" is a multidimensional construct that generally refers to events that produce a positive experience (White, 2011). In criminology, the notion that anticipated rewards shape offending behavior is a central argument in both rational choice theory (Becker, 1968) and social learning theory (Akers, 1985, 1998). In rational choice theory, rewards comprise a substantial component of the utility function and, in social learning theory, rewards are essential for the reinforcement process of learning behaviors. Empirical studies consistently show that rewards are related to criminal offending (Baker & Piquero, 2010) and strong predictors of deviant behaviors (Goldberg et al., 2002). Many types of rewards are found to be related to crime, like monetary rewards (e.g., Hochstetler et al., 2007; Uggen & Kruttschnitt, 1998) and social rewards (e.g., Akers, 1998; Hoeben & Thomas, 2019). Additionally, some scholars highlight the importance of physiological rewards, such as feeling a thrill or rush when engaging in criminal offending (Katz, 1988; Matsueda et al., 2006; Thomas et al., 2020). Unlike other rewards, the feeling of thrill or rush are often immediately experienced during the act rather than delayed, and the probability of experiencing thrill is often definite rather than uncertain (Katz, 1988). Further, physiological rewards are reported as one of the primary drives for why individuals commit certain offenses (Pfefferbaum & Wood, 1994).

Importantly, these physiological rewards may play a role in further elucidating the relationship between impulsivity and offending. Impulsivity is regularly found to be related to higher offending (Lynam & Miller, 2004), and it is a factor that can notably impact one's decision to engage in criminal behaviors. Indeed, individuals with higher

levels of impulsivity tend to place more emphasis on immediate rewards and are more sensation seeking (Gottfredson & Hirschi, 1990; Lynam & Miller, 2004; Whiteside & Lynam, 2001). Those who are more impulsive also tend to overvalue the thrill and rush of criminal offending (Katz, 1988; Pfefferbaum & Wood, 1994). Therefore, taking physiological rewards into consideration may help researchers understand more about the relationship between impulsivity and offending.

Dual-process theories can be a helpful framework in exploring how impulsivity and rewards matter in individual decision making. The dual-process theories suggest that there are two types of reasoning processes in judgement and decision making; one is autonomous and the other involves hypothetical thinking (Evans & Stanovich, 2013; Stanovich, 2011). The relative weight given to each system during choice making is dependent upon individual attributes like impulsivity (Kahneman, 2011). For instance, individuals who are more impulsive have a tendency to rely on Type I over Type II processes when making decisions, because they are apt to primarily engage in fast and autonomic thinking. Whereas those with lower levels of impulsivity tend to engage in slow, deliberate Type II processing, overriding the fast Type I processing (Hofmann et al., 2009).

There is evidence that suggests possible mediating and moderating pathways in how impulsivity and rewards affect criminal decision making. For mediation, scholars suggest that individuals who are more impulsive anticipate higher immediate rewards compared to those who are less impulsive (Hahn et al., 2009; Kerr et al., 2015). In other words, it is possible that one of the reasons impulsivity is related to offending is because impulsive people tend to expect greater physiological rewards. For moderation,

impulsivity may increase one's susceptibility to physiological rewards of crime because it provides immediate and certain gratification that can be more affected by a tendency of rapid Type I processing. That is, individuals with higher impulsivity are more sensitive to immediate physiological rewards because they tend to engage in Type I processes of decision making and tend less to utilize Type II processing. In addition, impulsivity is related to greater reward discounting (i.e., the overvaluation of immediate versus delayed rewards; Ainslie, 1975; Bechara & Damasio, 2002; da Matta et al., 2012), which suggests overweighing of physiological rewards for more impulsive people.

The full model of offending decision making should not only examine the influence of impulsivity on criminal behaviors, but also explore how immediate benefits of crime may matter for the relationship between certain personal attributes and crime. The current thesis examines first whether the impact of impulsivity on offending is indirect through the mediating relationship of physiological rewards, and second whether physiological rewards are differentially salient based on one's level of impulsivity. The question is addressed by leveraging longitudinal data from the Pathways to Desistance study, a study of serious juvenile offenders. In the end, this thesis will further assist the literature in clarifying potential mediating and moderating mechanisms regarding physiological rewards on impulsivity and criminal decision making.

Chapter 2: The Dual-Process Framework of Decision Making

Human decision making and reasoning have long intrigued scholars. One set of theories proposed to organize and understand human choice calculus is the dual-process theories. While there are various articulations of the dual-process model in many areas of research, they converge around a similar organization. The general framework of the dual-process models in judgement and decision making can be separated into two interdependent types of processing: Type I and Type II (Evans & Stanovich, 2013; Kahneman, 2011; Stanovich, 2011; Stanovich, 1999; Stanovich & West, 2000), also known as the 'hot' and 'cold' systems, fast and slow systems, or impulsive and reflective systems (see discussion in Evans & Stanovich, 2013; Skinner & Zimmer-Gembeck, 2007; Strack & Deutsch, 2004; van Gelder & de Vries, 2012, 2014). The two types of information processing can be viewed as antagonistic and they regulate and interact with each other during choice calculation. Some theorists assume the default-interactionist structure for the two processing, hypothesizing that Type I process will produce the default intuitive response in a given situation unless Type II process intervenes and takes over (Evans & Stanovich, 2013; Kahneman & Frederick, 2002; Stanovich, 2011).

The two types of processes can be distinguished via several defining features plus typical correlates or characteristics often associated with each processing type. Type I is defined as being autonomous and does not require working memory, meaning that it does not demand controlled attention (Evans & Stanovich, 2013). It is typically associated with being automatic, lower order, more immediate, and having fast execution times. The first type of processing often engages in rapid reaction-based

decision making to situational factors with little information or conscious processing, and it is associated with heuristics (Evans, 2003; Evans & Stanovich, 2013; Stanovich & West, 2000). Heuristics are "fast and frugal" mental shortcuts or strategies that make decision making simpler by ignoring excess information or utilizing stereotypes or experience (Gigerenzer & Gaissmaier, 2011; Tversky & Kahneman, 1974). When individuals rely on the first type of processing, they may make decisions that often lack considerations of future consequences. Type I processing also includes executing rules or decision making principles that have been conditioned or learned to the point of automation (Evans & Stanovich, 2013). On the other hand, the second type, Type II, requires working memory, mental simulation, and it is defined by cognitive decoupling, which is the ability to differentiate between beliefs and hypotheses (Evans & Stanovich, 2013). Type II processing is often correlated with being logical, calculating, higher order, effortful, and deliberate. Its processing is usually slower and more abstract (Evans, 2003; Stanovich & West, 2000). Therefore, the ability to analyze future consequences and to guide behavior that aligns with one's preferences typically requires Type II processing (Evans, 2012).

Neuroimaging studies show that different brain regions are activated when participants engage in heavy logic-based problems (Type II) compared to belief or reaction-based problems (Type I; De Neys et al., 2008; Tsujii & Watanabe, 2009). Experimental studies show that by suppressing working memory or increasing participant's time pressure, both of which decrease Type II processing, the rate of belief bias increases and logical accuracy decreases (De Neys, 2006; Evans & Curtis-Holmes, 2005). Belief bias, as Evans (2012) defines, is "the tendency to judge the validity of a

logical argument on the basis of whether one agrees with the conclusions" (p. 120). For example, using an illustration provided from Evans (2012), say one were to ask whether the following statement is correct: "if an animal is a dog, then it must have a tail." A default, heuristic Type I response would be "yes." But after some reflective thinking and consideration (i.e., Type II processing), the answer would be "no, not necessarily" because not all dogs have a tail.

A common fallacy supposes that reaction-based Type I thinking is 'bad' or error prone and reflection-based Type II processing is 'good' or rational (Evans & Stanovich, 2013; Pennycook et al., 2018). However, errors and cognitive biases are not always indicative of Type I thinking, and Type II process is not always responsible for ideal reactions in certain situations (Evans & Stanovich, 2013). "Fast and frugal" heuristic-based thinking, like that in Type I, can be adaptive if it is associated with evolutionary development and accumulation from prior experiences (Evans, 2007; Gigerenzer & Todd, 1999). For instance, Type I thinking would be adaptive in an emergency room when a patient is experiencing a heart attack and the doctor has to make a prompt judgement whether to treat the patient as high-risk or low-risk. Under time constraint, using heuristics and cues may result in a better outcome rather than evaluating numerous measurements and weighing the possible choices and consequences (Gigerenzer & Todd, 1999). Therefore, a dual-process model provides the framework for understanding the mechanisms by which individuals make decisions instead of the "rightness" of behavioral outcomes resulting from each process.

The idea of distinguishing two types of cognitive processes is not entirely new, as scholars have discussed variations of dual-process theories in papers since the 1970s

(e.g., Wason & Evans, 1974). Although the dual-process framework, and efforts similar to it, was not introduced to criminology until later, scholars have discussed within rational choice theory that the offender decision making process is not always rational, deliberate, thoughtful, or reasoned (McCarthy, 2002). In the explanation of offending, this framework is presented as a way of explaining within- and between-individual differences in response to environmental stimuli (i.e., engaging in crime) (de Vries & van Gelder, 2013; Mamayek et al., 2015; Paternoster et al., 2011; Paternoster & Pogarsky, 2009; Steinberg, 2010; Thomas & McGloin, 2013). Paternoster and Pogarsky (2009) explain the variation between people in how decisions are made using the notion of thoughtfully reflective decision making (TRDM). In the authors' words, TRDM reflects "the tendency of persons to collect information relevant to a problem or decision they must make, to think deliberately, carefully, and thoughtfully about possible solutions to the problem, apply reason to the examination of alternative solutions, and reflect back upon both the process and the outcome of the choice in order to assess what went right and what went wrong" (p.104-105). Similar to Type II processing, behavioral outcomes associated with TRDM are those resulting from slow and deliberate reasoning that are more consistent with the actor's preferences. TRDM is related to higher education attainment, better health, lower criminal engagement and substance use, and various positive life outcomes (Paternoster et al., 2011). In their study, Paternoster and colleagues (2011) also find that TRDM is associated to the accumulation of higher human, social, and cultural capital.

Other scholars have also integrated the dual-process framework in works addressing different criminological theories. De Vries and van Gelder (2013) use a

hot/cool perspective, similar to Type I and Type II processes, to explain predictors of criminal decision making. They find that negative affect (e.g., nervousness) was related to the hot processing condition and perceived sanction risk was associated with the cool processing condition. Thomas and McGloin (2013) use dual-process theory to explain the potential difference in susceptibility to normative peer influence and unstructured socializing for individuals with low and high levels of impulsivity. They find that adolescents with low impulsivity are more vulnerable to normative influence by deviant peers than are those with high levels of impulsivity, potentially because they tend to utilize Type II processing more than Type I. Yet, it is less clear from their results whether unstructured socializing would have a greater effect on one's delinquency for those with high impulsivity (i.e., individuals who tend to engage in Type I processes). Recent efforts integrating the dual-process framework in criminology have not only successfully demonstrated its usefulness in explaining variation in offending across people but also shown potential in making current explanations of crime more specific (Mamayek et al., 2015). Precisely, an avenue to explore is how dual-process theories can help us understand how rewards play a role in offending.

Criminal Rewards and Offending

Rewards are generally viewed as hedonistic pleasures or sensations (Marks, 2011). Rewarding events can also elicit positive affective experience which can strengthen behaviors on which the rewards are contingent (Thorndike, 1911; White, 2011). The type of rewards can range from food and sexual stimuli to money and social approval. The importance of rewards associated with criminal activities has long been

recognized by scholars in criminology. Of the many explanations of crime, two theoretical traditions have a core focus on the rewarding aspects of criminal behaviors.

One of the traditions is rational choice theory. This theory originates from early utilitarian perspectives of philosophers like Bentham and it is grounded on the assumption that human beings are rational decision makers and that behaviors are the results of such rational calculus (e.g., Becker, 1968; Grasmick & Bursik, 1990). More notably, Becker's (1968) introduction of the economic model of crime sets the groundwork for contemporary rational choice modeling using economic terms. Becker (1968) posits that when the expected utility of an act, be it legal or illegal, is greater than the expected utility of the alternative, a rational person would engage in the act. In other words, a rational decision maker would engage in criminal activities if the expected benefits from such activities exceed the expected cost. Hence, the major components involved in the economic model include the expected costs and the expected benefits of a criminal act. Furthermore, Clarke and Cornish's (1985; also Cornish & Clarke, 1986) model extends the classical and economic rational choice framework by suggesting two stages of choice – initial involvement and criminal event. First, individuals must make the decision to be criminally involved, and this decision is influenced by their background, prior learning, general needs, and incentives. Then the individual will decide the offense to commit using more situational information related to the criminal event and immediate circumstances. Like the economic model, Clarke and Cornish's (1985) model also recognizes the importance of rewards and costs in one's choice to commit a crime.

The second theoretical tradition with a heavy focus on rewards is social learning theory, which argues that deviant behavior is learned in the same way as prosocial behavior (Cressey, 1960). Developed from Sutherland's (1947) differential association, individuals engage in law-violating acts because of an excess of definitions favorable to violation of law over definitions unfavorable to violation of law. Akers (1985, 1998) extends Sutherland's notion of differential association by further specifying the process through which criminal behaviors are learned and the mechanisms in which the transference of criminal definition occurs (see also Burgess & Akers, 1966). Among the processes which Akers postulates, differential reinforcement most strongly relates to rewards (Akers, 1985, 1998). Differential reinforcement refers to the balance of anticipated or actual rewards and punishment consequent to behaviors (Akers, 1985, 1998). A rewarding outcome reinforces a behavior and increased the probability of that behavior being repeated, whereas a punishing outcome discourages a behavior and decreases the probability of repeating that behavior. According to social learning theory, an individual's criminal engagement is dependent on their past, present, and anticipated future rewards and punishments, which can be social or nonsocial.

Rewards are not only related to offending theoretically, but also empirically. Evidence suggests that various types of rewards consistently predict offending outcomes (e.g. Baker & Piquero, 2010; Nagin & Paternoster, 1993). Financial rewards of crime have been studied in criminology due to the influence of Becker's (1968) economic model, and actual and potential pecuniary returns from illegal activities have often been measured and examined under this model to understand the effects of financial rewards (e.g., McCarthy & Hagan, 2001). Despite Becker's (1968) focus on

examining economic returns, he also acknowledges that the benefits of crime can be conceptualized in many ways beyond money. One of such noneconomic rewards are the extrinsic social reinforcements, which include a broad range of tangible or intangible rewards as well as direct physical or verbal reactions from peers (Akers, 1998).

Aside from monetary and social returns, there are nonsocial rewards as well, such as physiological or intrinsic rewards. This category of rewards is considered the nonsocial rewards suggested by Akers (1998), which are also referred to as unconditioned physiological stimuli, physiological rewards, or psychic rewards (Katz, 1988; Matsueda et al., 2006; Thomas et al., 2020). Collectively, these terms cover emotional or physiological states which arise when engaging in deviant activities. Physiological rewards, like thrill and rush, are motivating factors for some individuals to commit crime. Katz's "Seductions of Crime" (1988) is one of the few works that brings intrinsic rewards to the center stage of criminal explanations. Katz elaborates on Bordua's (1961) suggestion that theorists should pay more attention to the enjoyment that accompanies offending. In Katz's (1988) description of physiological rewards, which he termed "sneaky thrills," criminals are often "seduced" into engaging in crime due to the prospect of excitement or kicks.

Excitement and thrill seeking associated with crime have been nominated as primary motivators of criminal engagement in adolescents and offenders (Kazemian & Le Blanc, 2004; Pfefferbaum & Wood, 1994). These physiological returns are considered primary rewards that have innate value necessary for homeostasis and reproduction, including food and excitement. Physiological reward is regarded as more

immediate (i.e., experienced during the act), short-term, and present (Ferrell, 1997). Furthermore, some offenders also refer to the immediate excitement and thrill as "adrenaline rush," and this emotional stimulation is viewed as an integral part of the offending experience (Ferrell, 1997).

Physiological rewards are also related to the concept of sensation-seeking. Sensation-seeking is "the extent to which an individual places a strong, absolute, or relative emphasis on the pleasures of crime" (Agnew, 2016, p. 184). Another view of sensation-seeking is the generalized tendency to seek novelty, excitement, thrill, or fun (Zuckerman, 2010), which includes four parts: thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility (Zuckerman, 1971). Of the dimensions, physiological rewards is a critical part of thrill seeking. Studies find that individual who are more inclined to seek thrills and excitement are more likely to engage in risky sexual activities (Donohew et al., 2000), substance use (Hittner & Swickert, 2006; Magid et al., 2007), and antisocial behaviors (Byck et al., 2015).

In the dual-process framework, rewards can matter based on their certainty and temporal property. Physiological rewards are instantly gratifying and tend to be more certain (Katz, 1988), unlike, for example, monetary rewards which have a probability of not delivering if one was caught (Wright & Decker, 1997). Under the default-interactionist perspective, Type I processing provides a rapid default response unless inhibited or overridden by Type II processing (Evans & Stanovich, 2013; Kahneman & Frederick, 2002). A decision for immediate reward is associated with Type I thinking, whereas a mental simulation for a delayed reward requires Type II processing that contemplates future possibilities (Evans & Stanovich, 2013; Quartz, 2009). A

reflective Type II processing allows individuals to have the ability to resist from immediate gratification of the physiological rewards (Strack & Deutsch, 2004). Therefore, a greater tendency for Type I process over the regulatory systems (i.e., Type II) will result in a higher likelihood of decisions driven by immediate rewards (Geier & Luna, 2009). Furthermore, evidence shows distinct neural systems of decision making for immediate or delayed monetary rewards that are potentially associated to Type I and Type II processes (McClure et al., 2004), suggesting that an increase in regions related to heightened reward reactivity may bias one's decision toward immediate rewards (Geier, 2013). The immediacy and certainty of physiological rewards are also important in the discussion of the characteristics and behavioral tendencies associated with impulsivity.

Impulsivity and Offending

Impulsivity is a complex construct with many definitions across different disciplines (Bakhshani, 2014). From a personality perspective, it reflects a tendency to make up one's mind quickly, to engage in unplanned risky behaviors (Eysenck, 1993), and to act with little considerations of the future (Dickman, 1993). Biological, neurological, and cognitive viewpoints characterize impulsivity as a failure to inhibit impulses (Chamberlain & Sahakian, 2007; Chudasama, 2011), and from a behavioralist perspective, impulsivity is described as not being able to consider various consequences and inability to delay gratification (Evenden, 1999; Monterosso & Ainslie, 1999). The overlap across the multiple definitions generally covers a tendency for urgency and a lack of premeditation (e.g., Eysenck & Eysenck, 1977; Lynam & Miller, 2004).

Many areas of research and clinical work have discussed the influence of impulsivity on behavior. Impulsivity plays a prominent role in theories of personality (e.g., Eysenck & Eysenck, 1978), diagnoses of psychopathology (e.g., American Psychiatric Association, 2013), as well as explanations of psychopathy (e.g., Lynam, 1996) and substance abuse (Wills et al., 1994). One's level of impulsivity and related individual characteristics have also been examined in criminology. Impulsivity as a construct holds theoretical importance, and it also has strong empirical relationship with offending behaviors (Baron, 2003; Cooper et al., 2003; White et al., 1994; Wright et al., 2004). Individuals with higher levels of impulsivity are more likely to offend (e.g., Bechtold et al., 2014), engage in more delinquent behaviors (Pratt & Cullen, 2000), begin offending at an earlier age (Carroll et al., 2006), and continue offending (Monahan et al., 2009).

Theoretically, proponents of the criminal propensity perspective argue that there are enduring individual differences between offenders and non-offenders that are related to one's level of impulsivity. Wilson and Herrnstein (1985) propose that offenders have certain personality traits which include the inability to delay gratification and a lack of capability to plan for the future. Similarly, Gottfredson and Hirschi (1990) contend that offenders and non-offenders differ in their levels of self-control. In their proposition, offenders who lack self-control are also impulsive, unable to defer gratification, and discount delayed consequences. In addition, Grasmick and colleagues' (1993) widely-used scale for measuring self-control includes impulsivity as one important domain of Gottfredson and Hirschi's conception of self-control.

Although self-control in the general theory of crime is thought to include impulsivity, self-regulation, and risk taking (Gottfredson & Hirschi, 1990; Grasmick et al., 1993), it is important to highlight they are three related but empirically distinct constructs (Burt, 2020; Hofmann et al., 2009; Mamayek et al., 2015; Nigg, 2017). Burt and colleagues (2014) and Forrest and colleagues (2019) demonstrate that "self-control," as traditionally defined, may be composed of two elements – impulsivity and risk-taking – which have their own developmental trajectories. Moreover, Mamayek and colleagues (2015, 2017) redefine self-control as self-regulation, which is the ability to supersede impulsive tendencies, and they suggest that impulsivity should be thought of as the motivation or drive and self-regulation as the restraint. Mamayek and colleagues (2017) further demonstrate that impulsivity and self-control are empirically distinct and predict intentions to offend differently. In psychology and neuroscience, impulsivity and self-control are two different and antagonistic concepts (Kalenscher et al., 2006; Nigg, 2017). In a review of the terminologies and studies of self-control and other related constructs, Nigg (2017) states that self-control (or inhibition) is the intrinsic regulation of action, emotion, and cognition. On the other hand, impulsivity is viewed as "nonreflective selection or preference for the immediately rewarding response" (p. 370).

Importantly, individual levels of impulsivity can influence decision making. Individuals with higher levels of impulsivity are apt to make decisions based on non-cognitive cues, such as affective and physiological cues (e.g., excitement), as opposed to evaluating the consequences (Donohew et al., 2000). This suggests that more impulsive individuals will prefer and be more dependent on the thrill and rush of crime.

Moreover, the dual-process framework can be helpful in understanding how impulsivity affects decision making and reasoning. The difference between the two types of reasoning processes has often been shown to map on to individual levels of impulsivity (e.g., Thomas & McGloin, 2013; van Gelder & de Vries, 2012). One can find similarities in the language used to describe the dual processes and aspects of impulsivity (Nagin & Pogarsky, 2003; Paternoster & Pogarsky, 2009). For example, Paterson and Newman (1993) discuss impulsive behaviors as "directly related to lack of prospective reflection or, in other words, a lack of planful thought and sound judgement" (p. 722) and Nigg (2017) discusses impulsivity as "nonreflective selection" (p. 370). These two descriptions of impulsivity are similar to the characteristics (or absence) of Type II processing. A defining feature of Type II process is the ability to "create temporary models of the world and test out actions (or alternative causes)" (p. 22), which requires planning, reflection, and judgement (Stanovich, 2011).

Engagement in Type I and Type II reasoning involves different levels of self-regulation, and the tendency to utilize one type of processing over the other differs across persons and across situations within persons (Kahneman, 2011). Individuals with higher levels of impulsivity are apt to make reactive decisions and engage in less deliberate activities, resulting in behaviors utilizing Type I decision making more. In contrast, individuals with lower levels of impulsivity are hypothesized to engage in Type II decision making more (Kahneman, 2011). In an experiment, individuals who are more impulsive, more impatient, and less able to defer gratification are more likely to utilize Type I thinking and produce more errors based on intuitions and heuristics when they are asked to solve logical puzzles (Frederick, 2005). Moreover, the two

systems interact with each other to produce certain behavioral decisions, but individuals may differ on the weight they attribute to each system depending on their level of impulse control (Hofmann et al., 2009). For example, the risk of drinking and driving is highest for individuals who are more impulsive (i.e., Type I thinking) and have less self-regulation (i.e., Type II thinking), whereas individuals with inverse characteristics (i.e., low impulsivity and high self-regulation) showed the lowest intentions to drink and drive (Mamayek et al., 2015). These studies may suggest that certain factors may pose differential risks to individuals with varying levels of impulsivity as they may affect their decision making processing.

Integration of Criminal Rewards and Impulsivity

The language used in the impulsivity literature often overlaps with the concept of rewards. In describing impulsivity, some scholars have viewed it as the preference for and overvaluation of immediate rewards (Ainslie, 1975). Some state that individuals with higher impulsivity are unable to resist immediate rewards in exchange for delayed rewards (i.e., deferred gratification; Monterosso & Ainslie, 1999). A common-ground between impulsivity and rewards merge in the discussion of reward discounting. This pattern of discounting is referred to as hyperbolic discounting or present bias in the psychology and economics literature (O'Donoghue & Rabin, 1999, 2015). In general, it posits that human actions are biased towards the present moment, but the proposed functional form of the discounting varies slightly across psychologists and economists (O'Donoghue & Rabin, 2015). The process implies that when an individual is presented with the option of an immediate reward or a delayed reward, values for the two rewards are assigned, and the reward associated with the higher present value will be chosen

(da Matta et al., 2012). Individuals who discount or decrease the value of a delayed reward at a higher rate are more biased towards choosing the immediate option (da Matta et al., 2012). Although people in general discount rewards that are more distant in the future, individuals higher in impulsivity show a more pronounced decline in their function of reward discounting (Ainslie, 1975; Lutz & Widmer, 2014). In other words, more impulsive individuals tend to place higher values on short-term rewards (Hoeben & Thomas, 2019; Wittmann & Paulus, 2008) and they tend to prefer an instant but smaller reward instead of a larger delayed reward (Ainslie, 1975; Peters & Büchel, 2010; Steinberg et al., 2009), suggesting an overvaluation of short-term rewards (Bechara & Damasio, 2002; Kurth-Nelson et al., 2012) or greater sensitivity to immediate rewards (Martin & Potts, 2004; Moeller et al., 2001).

It is possible that the discounting of future rewards is a consequence of the increased uncertainty of delayed rewards and the certainty of immediate rewards (Ainslie, 1975; O'Donoghue & Rabin, 2015). People tend to prefer the outcome with a certain gain over an alternative with some risk of losing, known as the certainty effect (Tversky & Kahneman, 1992). This is true even when the probabilistic outcome has a higher expected value than the certain one. Estle and colleagues (2007) find that when reward is certain, the discounting rate for primary rewards tend to be steeper than that of monetary rewards. On the other hand, when reward is probabilistic, there is no difference in the discounting of primary and monetary rewards (Estle et al., 2007).

Another perspective on the relationship between rewards and impulsivity is that neuroimaging research suggests impulsivity is associated with mainly two regions of the brain, one responsible for the salience of reward's affective response (i.e.,

amygdala) and the other related to hedonic anticipation of rewards (i.e., striatum and anterior cingulate cortex) (Kerr et al., 2015). For instance, studies find that individual level of impulsivity is correlated with greater anticipation of monetary rewards (Hahn et al., 2009) and primary rewards (Kerr et al., 2015). Kerr and colleagues (2015) demonstrate that after participants are given a reward cue or stimuli, impulsivity is positively correlated with higher anticipation activity in regions related to reward sensitivity. Another study also suggest greater impulsivity or hyperactivation in regions related to increased expectancy of an immediately available reward (Bouchard et al., 2012). In other words, this may suggest that individuals with higher impulsivity tend to expect greater immediate rewards than those with lower impulsivity.

Despite the overlap between impulsivity and rewards, scholars state that they are distinct concepts, and the similarity results from the strong relationship between the two concepts rather than having the same underlying construct. Dawe and Loxton (2004) and other scholars (e.g., Caseras et al., 2003; Franken & Muris, 2006; Miller et al., 2004; Moeller et al., 2001; Quilty & Oakman, 2004) suggest that impulsive behavior has two parts, with the first domain representing a tendency to act rashly and a lack of evaluation of consequences (i.e., rash impulsivity) and the second domain characterized by enhanced sensitivity towards rewards, especially immediate rewards. Evidence shows that reward sensitivity and impulsivity both affect the increased likelihood of drug use, but they provide independent contributions to the initiation, continuation, and abstinence in substance use (Dawe et al., 2004; de Wit & Richards, 2004). Additionally, the two constructs are correlated to activation in different neural pathways (Geier & Luna, 2009; Loxton et al., 2008). The strong association between

the two concepts can elucidate to specific mechanisms of how rewards are involved in the association of impulsivity and offending.

Physiological Rewards and Mediation

Neuroimaging studies and the dual-process theories can shed light on the potential mediating pathway of rewards. Impulsivity is positively associated with activation in the more immediate and primary brain regions, such as the ventral striatum (Hariri et al., 2006), and heightened ventral striatum activity is also related to individual tendency to respond to primary, immediate, and short-term rewards (Galván, 2013; Hariri et al., 2006; McClure et al., 2004). Additionally, impulsivity is associated with greater activation in brain regions related to reward anticipation (Bouchard et al., 2012; Hahn et al., 2009; Kerr et al., 2015). Although the neuroimaging studies here are correlational and are not evidence of causal mechanisms, it is reasonable to question whether more impulsive individuals may show greater reward anticipation leading to a higher likelihood of engaging in behaviors in order to receive the reward.

The dual-process framework suggests that individuals with higher impulsivity tend to rely on Type I processing and often lack Type II thinking when making decisions (Kahneman, 2011). Moreover, their expectation of reward tends to be represented by the heuristic process and influenced by the anticipation of positive affect (e.g., excitement) (Quartz, 2009). Therefore, individuals with higher impulsivity may anticipate greater physiological rewards due to reliance on Type I processing that can be biased by feelings and excitement. Individuals who are more impulsive may likely perceive and anticipate greater immediate physiological rewards compared to those who are less impulsive. And when one anticipates the immediate rewarding factor of

delinquency as higher, the likelihood of engagement in the behavior should increase as well.

Compared to the moderation hypothesis discussed below, there are fewer studies that discuss the mediating relationship that physiological rewards may have on impulsivity and crime. Nagin and Paternoster (1993) suggest that low self-control may be indirectly associated with offending intent via perceived criminal utility (i.e., perceived psychic rewards), sanctions, and shame. Piquero and Tibbetts (1996) also find that the relationship between low self-control and intention of shoplifting or drunk driving is mediated through perceived pleasure (i.e., fun or kick) of offending. Even though both studies use Grasmick and colleagues' (1993) measure of low self-control with impulsivity included instead of directly testing impulsivity, they still suggest the potential influence of an individual's perception of criminal rewards. These scholars hint that impulsivity may affect offending through indirect pathways, but few have tested impulsivity or physiological rewards specifically.

Physiological Rewards and Moderation

It has been suggested that impulsivity may increase one's vulnerability to other criminogenic risks, including the attractions and incentives for deviant behaviors (e.g., Lynam et al., 2000). Studies demonstrate that impulsivity may interact with deviant peer association (Vitulano et al., 2010) and neighborhood context (Lynam et al., 2000; Zimmerman, 2010) to influence offending. For instance, the relationship between impulsivity and juvenile offending tends to be higher in poorer neighborhoods compared to more affluent neighborhoods (Lynam et al., 2000). Moreover, impulsivity is also associated with sensation-seeking and the desire for excitement and stimulation

(Lynam & Miller, 2004; Mann et al., 2018; Whiteside & Lynam, 2001). Individuals with higher levels of impulsivity are not only more likely to offend (Lynam & Miller, 2004; Matsueda et al., 2006) but also tend to find the thrill of crime as more rewarding (Pfefferbaum & Wood, 1994). In addition, individuals who are more sensation-seeking tend to view crime or risky activities as more rewarding and pleasurable (Katz, 1988).

Under the concept of reward discounting, individuals with higher impulsivity have a steeper discounting function for delayed rewards, and the value of perceived short-term immediate rewards tend to be overestimated (Ainslie, 1975; O'Donoghue & Rabin, 2015; Peters & Büchel, 2010). Additionally, individuals who tend to place a greater value for immediate rewards also have a tendency to place greater value on more certain rewards as well (Green & Myerson, 2004). Physiological rewards are often immediately felt during the criminal act and have a higher certainty of receipt (Ferrell, 1997; Katz, 1988). Hence, highly impulsive individuals may overvalue short-term immediate rewards (Ainslie, 1975; Bechara & Damasio, 2002; Hoeben & Thomas, 2019), which may make them more susceptible to the physiological rewards of crime.

Individuals who are more impulsive are inclined to make decisions based on non-cognitive cues, like thrill or excitement (Donohew et al., 2000). Under dual-process theories, those who are more impulsive already have the tendency to utilize Type I over Type II process (Hofmann et al., 2009; Kahneman, 2011), making them more vulnerable to the cues of criminal attraction (Mamayek et al., 2015). For instance, impulsivity can make one more susceptible to immediately rewarding stimuli by engaging less in the analysis of future consequences which requires Type II processing

(Geier & Luna, 2009). The more distant and uncertain a reward is, the more it requires cognitive processes, like that of Type II decision making, to process the value of the reward (Kurth-Nelson et al., 2012; Stahl et al., 2014). In this case, individuals with higher impulsivity may weight immediate physiological rewards greater than those with lower levels of impulsivity, making them more vulnerable to engage in criminal activities when these rewards are present.

Current Study

Prior studies that have looked at the relationship between rewards and offending have primarily included impulsivity (or self-control) as a control for the models (e.g., Carmichael & Piquero, 2004; Matsueda et al., 2006). Or the inclusion of rewards and impulsivity is used to compare focal correlates from different theories (e.g., Baron, 2003; Wright et al., 2004). For instance, researchers include rewards and impulsivity in the same regression model as a means to compare the explanatory power for social learning theory and the general theory of crime (see discussion in Pratt et al., 2010; Pratt & Cullen, 2000). Prior studies allude to the potential of moderating relationship between impulsivity and rewards but few tests the effect (Sellers, 1999). Evidence for the direct effects of impulsivity on offending and rewards on offending is quite strong. However, the current literature is still unclear regarding how rewards matter as part of the process that connects impulsivity and criminal behavior. Without the knowledge of how rewards of crime may affect the impulsivity-offending relationships, the extant literature could be missing an integral portion of the offending decision making calculus.

Using the Pathways to Desistance data, the current thesis examines what potential role physiological rewards play in explaining the relationship between impulsivity and crime. From the arguments made above, I have two hypotheses:

Hypothesis 1: Perceived physiological rewards will mediate the relationship between impulsivity and offending.

Hypothesis 2: The relationship between perceived physiological rewards and offending will be stronger for individuals with higher levels of impulsivity.

The Pathways to Desistance sample can provide insight into the decision-making calculus for serious juvenile offenders. The Pathways data allow for investigation into physiological rewards for self-reported offending behaviors. In addition, the longitudinal aspect of the Pathways data allows us to establish temporal ordering in the offending outcome and predictors. In the end, the current thesis will contribute to the existing literature by exploring whether the relationship between impulsivity and offending can be mediated or moderated by physiological rewards. Using the dual-process framework, this will provide more clarity and specificity to the existing knowledge of criminal decision making.

Chapter 3: Data and Methods

Data and Sample

Data from the multi-site Pathways to Desistance Study are used in the current thesis. The study consists of 1,354 serious juvenile offenders from Phoenix, AZ (i.e., Maricopa County, N=654) and Philadelphia, PA (N=700). Participants in the study were followed from adolescence into young adulthood over 11 waves between 2000 and 2010. The participants were all found guilty of a serious offense, comprising mostly of felonies or serious misdemeanors (i.e., weapon offense or sexual assault), and they were also between the ages of 14 and 18 at the time of their committing offense. To preserve heterogeneity in offense type, the sample capped drug offenses for male offenders at 15% at each site because drug offenses accounted for a large portion of all offenses committed by juveniles, especially males (Mulvey & Schubert, 2012). Two thousand and eight eligible individuals were approached for the study, and 1,354 consented to participate, resulting in a 67% response rate. Follow-up interviews were conducted every 6 months for 3 years and then every 12 months for another 4 years (i.e., 6, 12, 18, 24, 30, 36, 48, 60, 72, 84 months after initial baseline interview) with an average retention rate of 89.5%.

The current thesis uses data from waves 2 and 3 (6-month and 12-month interviews) because they provide the largest sample size and the least amount of missing data of any other follow-up interviews. Wave 1 is not used due to the fact that the impulsivity measure was not collected until wave 2. To account for temporal ordering, covariates at wave 2 are used to predict the outcomes at wave 3. Namely, impulsivity and physiological rewards are measured using wave 2 and offending

outcomes are from wave 3. Despite the fact that impulsivity and physiological rewards are both taken from the same wave, the correct temporal ordering may be established by the wording of the questionnaires. Although impulsivity is not constant across an individual's life-course, it tends not to fluctuate greatly within short periods of time (Burt et al., 2014; Forrest et al., 2019). Thus, although the data capture the respondents' current impulsivity at wave 2, one may reasonably assume that this attribute was relatively stable in the prior months. Because the rewards question asks participants their current perceptions about the thrill or rush associated with engaging in criminal acts, it is not unreasonable to view it as a potential mediator.

Using a sample of serious juvenile offenders to test the hypotheses under focus here does pose certain limitations. Due to data collection procedures and sample characteristics, the current sample is neither random nor representative of adolescents at large or even the general juvenile offender population, which largely limits the generalization of any findings beyond this sample. Moreover, a serious delinquent sample may not include many individuals with low levels of impulsivity given that it is positively associated with greater criminal engagement (e.g., Monahan et al., 2009; White et al., 1994). Hence, compared to a general sample of adolescents, the current sample has a higher probability of capturing the right end of the impulsivity distribution. This may limit the study's ability to detect differences between individuals with 'lower' impulsivity and those with higher impulsivity because of the narrower variation in the sample. This may be true for perceived physiological rewards as well because thrill and rush of crime are also correlated with higher offending behaviors (e.g., Matsueda et al., 2006).

Despite the shortcomings of the Pathways dataset, it does have the benefit of allowing for the examination of perceived physiological rewards, impulsivity, and detailed self-reported offending behaviors. Even though the variation of impulsivity and physiological rewards in a serious offender sample may be smaller compared to a general sample, there is still heterogeneity within this sample. And although findings from the current sample cannot be generalized, it is still worthy of investigation as it may assist in examining how physiological rewards play a role for those with higher levels of impulsivity or for those who are already involved in the criminal justice system. Historically, there is a substantial portion of influential criminological research built on nonrepresentative samples/serious offenders that have contributed greatly to our understanding of the explanation of crime (e.g., Hoffmann & Cerbone, 1999; McGloin & Thomas, 2016; Nagin & Paternoster, 1994). In addition, the Pathways sample has also been used by many scholars to shed light on offender decision making (e.g., Anwar & Loughran, 2011; Loughran et al., 2016; Mamayek et al., 2017; Thomas et al., 2020). Lastly, because criminal events are considered rather rare events, the current sample provides greater variation in the offending outcome than would a general sample.

Measures

Dependent Variables

Self–Reported Offending. Adolescents' self-reported involvement in antisocial and illegal activities is measured using the adapted self-reported offending (SRO) questionnaire from Huizinga and colleagues (1991). The measure is from participants'

responses regarding their engagement in 11 items of different types of crime in the 6-month recall period: (a) destroyed or damaged property, (b) entered building to steal, (c) shoplifted, (d) stolen car/motorcycle, (e) shot someone, (f) shot at someone, (g) robbery with weapon, (h) robbery without weapon, (i) beaten up someone badly and needed doctor, (j) been in fight, and (k) broke into car to steal. The 11 types of crimes are associated with the types of crime asked in the measure of physiological rewards. Among these crime types, (b) enter building to steal and (k) broke into car to steal are combined to form entering building or car to steal, (e) shot someone and (f) shot at someone are collapsed into shot at someone, (g) robbery with weapon and (h) robbery without weapon are collapsed to form robbery with/without weapon, and (i) beaten up someone badly and needed a doctor and (j) been in a fight are combined to form engagement in a fight. Combining these responses prevents potential double-counting of the same incident but still captures engagement in these similar types of behavior.

Given that some participants report an offending frequency that is unreasonably high (e.g., over 1,000 offenses) a variety score is used in the current thesis. The variety score is calculated by scoring the number of type of offenses the respondent engaged in during the recall period, ranging from 0 to 7. For example, if someone were to report that they entered a building to steal, stole a car, and been in a fight, they would have a variety score of 3, regardless of how many times they committed these acts. A variety score is shown to have higher validity and reliability compared to offending frequency, as frequency is more vulnerable to outliers (Sweeten, 2012).

It may also be informative to examine whether the relationships under study are specific to the types of offending – that is, whether physiological rewards for a certain

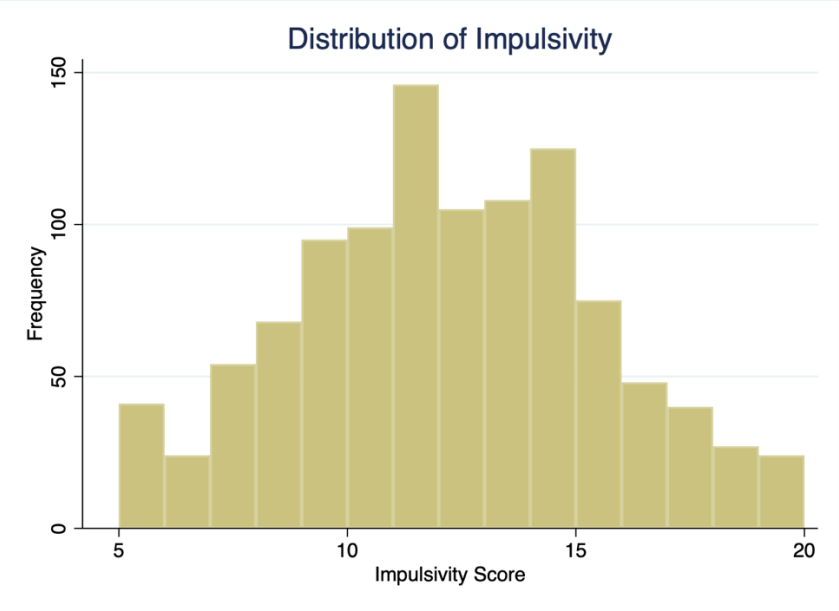
crime category better predict that type of offenses. Therefore, crime-specific variety scores are also calculated for two aggregated crime types: property crime and violent crime. Property crime includes destroyed or damaged property, entered building or car to steal, shoplifted, and stolen car/motorcycle. Violent crime includes shot (at) someone, robbery with/without weapon, and been in fight. The items for these measures and others are also listed in Appendix A. The current thesis uses offending measures from wave 3 (i.e., 12 months) to account for temporal ordering of the predictors and outcomes. The average variety score for all crimes is 0.810 (SD=1.232), for property crimes is 0.267 (SD=0.698), and for violent crimes is 0.543 (SD=0.743).

Independent Variables

Impulsivity. Impulsivity is measured using a subscale in the Youth Psychopathic Traits Inventory (YPI). The YPI subscale of impulsivity is the sum of 5 items which asked the participants to rate how they most often feel or think of certain things, consisting of statements like "I prefer to spend my money right away rather than save it," "I consider myself as a pretty impulsive person," "It often happens that I talk first and think later," "If I get the chance to do something fun, I do it no matter what I had been doing before," and "It often happens that I do things without thinking ahead." The responses were 1 (does not apply at all), 2 (does not apply well), 3 (apply fairly well), and 4 (apply very well), with the final impulsivity score ranging from 5-20 (α=0.65). The mean of individual impulsivity score in wave 2 is 11.73 (SD=3.329), and the z-score standardized values will be used in the model. The standardized score is used to better interpret the coefficient estimates in the interaction model and an alternative to mean-centering (Marquardt, 1980).

There is variation in the level of impulsivity across individuals (M=11.73, SD=3.329), even though the sample is comprised of serious delinquents. The distribution of impulsivity also demonstrates that some individuals do fall on the lower end of the impulsivity scale (Figure 1). This suggests that the sample may not be as biased towards higher impulsive individuals as one might initially assume. Social desirability bias (Nederhof, 1985) can be a possibility as to why the impulsivity scale is lower than expected, such that respondents may report being more thoughtful and reflective than they actually are.

Figure 1. Distribution of the Impulsivity Scores



Anticipated Perceived Physiological Rewards of Crime. Physiological rewards of crime are captured using the Indices of Personal Rewards questionnaire. The items are adapted from Nagin and Paternoster (1994) to capture the perceived thrill or rush of several types of crimes. This measure is the mean of the 7 items: (a) fighting, (b) robbery with a gun, (c) stabbing someone, (d) breaking into a store or home, (e) stealing clothes from a store, (f) vandalism, and (g) auto theft. Participants responded how much thrill or rush it is to engage in each of these acts on a 10-point scale from 0 (no fun or kick at all) to 10 (a great deal of fun or kick). If the participant has never committed an act, they were asked to rate their prediction of how much thrill or rush they think they will get by engaging in the act. Responses from wave 2 are included in the analysis (α=0.90). The standardized z-score version of this measure is also used in the models

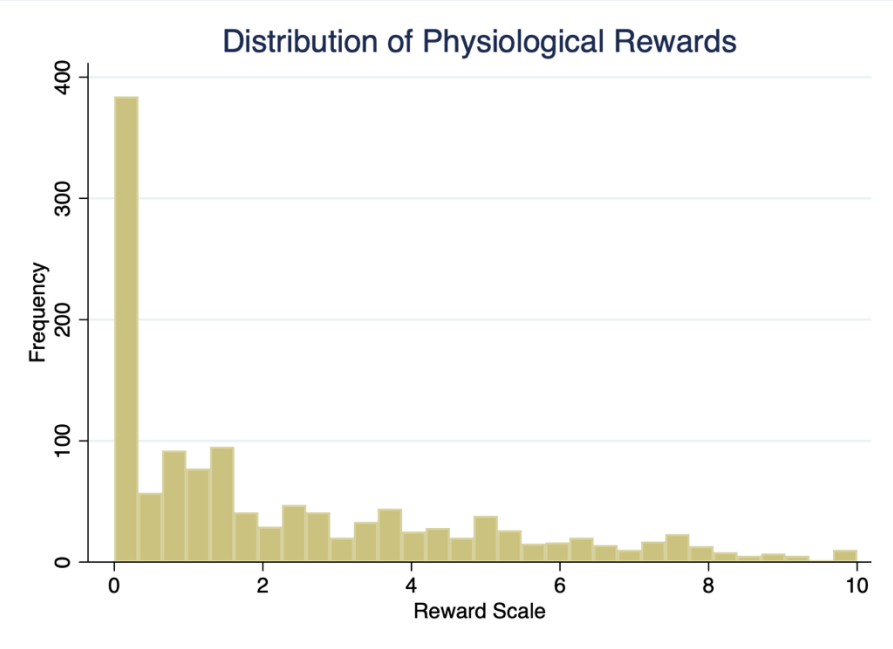
(Marquardt, 1980). The mean score for physiological rewards prior to standardization is 2.27 (SD=2.49).

Physiological rewards for specific crime types are also computed. Rewards related to property crimes include breaking into a store or home, stealing clothes from a store, vandalism, and auto theft. Rewards related to violent crimes include fighting, robbery with a gun, and stabbing someone. Although the exact items used in the questionnaire for physiological rewards do not completely match those asked in the self-report offending survey, the behaviors are highly related. The mean score for physiological rewards of property crimes is 2.08 (SD=2.61) and the mean score for physiological rewards for violent crimes is 2.53 (SD=2.71).

The initial descriptive statistics and distribution (Figure 2) of physiological rewards show that there is variation between individuals on their levels of perceived thrill or rush of crimes. Interestingly though, the overall sample tend to report lower levels of physiological rewards with many 0 values (26.09%). There may be three speculated reasons for the lower perceived physiological rewards. Experience with offending can potentially influence the perception of physiological rewards, so that certain types of crime may become less thrilling the more times it is engaged. Because the current sample is composed of individuals who have been convicted of a prior offense, their prior history with delinquency can reasonably play a role in why the rewards measure is heavily skewed. Second, the high proportion of 0 values in physiological rewards can likely reflect individuals who value other types of criminal rewards more, and for that reason do not perceive crime to be thrilling. Third, social desirability effect can also bias the distribution of physiological rewards downward,

similar to the impulsivity scale. Finding crime to be thrilling or exciting may not be a positively desired attribute that respondents want to report highly on, which may consciously or unconsciously lead to lower answers on their perceived physiological rewards of crime.

Figure 2. Distribution of Perceived Physiological Rewards Scale for All Crimes



Control Variables

Peer Delinquency. Deviant peers are a robust and consistent correlate of offending (e.g., Haynie, 2002; McGloin & O'Neill Shermer, 2009; Warr, 2002). Additionally, the relationship between peer delinquency and offending is also moderated by impulsivity (Thomas & McGloin, 2013), and scholars have noted that peers can shape decision making processes (Gardner & Steinberg, 2005; Hoeben & Thomas, 2019). Peer delinquency is measured using a questionnaire adopted from the Rochester Youth Study (Thornberry et al., 1994) that asked respondents about their friends' antisocial activities for 12 items (e.g., "During the recall period how many of your friends have gotten into a physical fight?") on a 5-point Likert scale, ranging from 1 (none of them) to 5 (all of them). The measure from wave 2 is used and the mean of

the 12 items is computed for the scale (α=0.89). The average peer delinquency score is 1.963 (SD=0.875).

Maternal Care. Maternal care is included in the model to control for the association between social control and one's level of impulsivity as well as its potential influence on perceived rewards. The measure is adopted from a subscale in the Quality of Parental Relationships Inventory (Conger et al., 1994) that assesses maternal affective tone to the respondents. The subscale includes 9 items, such as "How often does your mother let you know she really cares about you?"[1] Respondents rated the items on a 4-point scale from 1 (never) to 4 (always), with a higher score indicating a more supportive relationship. The mean of the 9 items at wave 2 is used in the analysis (α=0.93). The average maternal care score is 3.191 (SD=0.721).

Perceived Risk of Punishment. Evidence shows that an individual's perceived risk of punishment is related to offending (Loughran et al., 2012; Shulman & Cauffman, 2013) and one's level of impulsivity also has implications on their risk perceptions (Wilson et al., 2017). The measure is adopted from Nagin and Paternoster (1994) that captures the participant's perceived certainty of punishment for crime. Participants were asked the likelihood that they would be caught and arrested for the following 7 items: (a) fighting, (b) robbery with gun, (c) stabbing someone, (d) breaking into a store or home, (e) stealing clothes from a store, (f) vandalism, and (g) auto theft. The responses range from 0 (no chance) to 10 (absolutely certain to be

[1] The "mother" referred to in the questions can be any female adult responsible for raising the adolescent, so it is not limited to their biological mother.

caught). The measure is taken from wave 2 and the mean of the 7 items is used (α=0.90). The average score of perceived risk of punishment is 5.194 (SD=2.989).

Proportion of Time Spent on the Streets. The time that respondents could spend in the community (as opposed to in some sort of institution) can influence the opportunity they had to engage in criminal acts. Therefore, the proportion of time in the 6-month recall period that the respondent spent outside a facility without community access (e.g., prison, jail, detention center, etc.) is included in the analysis to control for varying opportunities of offending between individuals. A higher value indicates a greater proportion of time spent on the streets. The mean proportion of time respondents spent on the streets during the recall period is 0.521. This indicates that the average respondent spent about half of the recall period outside an institutional facility, which suggests that the self-reported offending measure captures criminal engagement for an average of only 3-months instead of the whole 6-month recall period.

Study Site. The location where the study and interview was conducted is coded as 1 for Philadelphia, PA and 0 for Phoenix, AZ.

Age. Age of the participants at wave 2 is coded as the integer value (e.g., 14 years and 7 months is coded as 14 years old).[2]

Race/Ethnicity. Race and ethnicity of the participants are coded as dummy variables for *White*, *Black*, *Hispanic* and *Other*. The participant's original self-reported race and ethnicity included more granular categories (e.g., Asian, etc.). However, due

[2] The continuous measure for age is only available in the restricted dataset. It is highly unlikely that the difference between the continuous and integer values of age would affect much of the results. Compared to using a continuous measure, the integer measure of age used in the current thesis will have a lower variance and granularity.

to the small sample size for certain categories, this coarser variable is provided by the Pathways study researchers to preserve the confidentiality of participants in the public access data.

Gender. The gender of the participant is coded 1 as male and 0 as female using the participant's reported gender.

Socioeconomic Status (SES). SES is measured using the mean of mother and father Index of Social Position (ISP) scores at wave 1, which accounts for both maternal and paternal education and occupation status (Hollingshead, 1957). Education is coded on a 7-point scale ranging from 1 (professional degree) to 7 (less than seven years of school). Occupation is also coded on a 7-point scale from 1 (higher executives, proprietors, major professionals) to 7 (unskilled employees). If the parent was the collateral reporter, responses for education and occupation from the collateral report are used. Otherwise, the response with a lower education and occupation from either the participant self-report or the collateral report is used. The following is how the ISP score is calculated (Hollingshead, 1971):

$$ISP = Occupation\ score \times 7 + Education\ score \times 4$$

SES is coded missing if both the mother and father education and occupation information is missing. If one parent's scores are unavailable, parental ISP score is calculated using the available parent's information. If either education or occupation information is missing, then the same score for one scale is used to derive the score for the other. The scale is reverse coded so that lower values indicate lower SES. The mean score for SES in the sample is 36.59 (SD=12.30).

Prior Offending. The experience that individuals have on certain type of criminal behaviors may influence their future offending as well their perception of physiological rewards. Therefore, history of offending will be included in sensitivity tests to control for prior experience with offending. The experience that respondents have with prior offending is measured using a lagged dependent variable (Huizinga et al., 1991). Respondents at wave 1 were asked if they have ever engaged in offending, and respondents at wave 2 were asked about their offending for the 6-month recall period. Reponses from wave 1 and wave 2 are combined to capture whether respondents have *ever* engaged in the types of crimes in the dependent variable prior to the wave 2 recall period. Measures of prior experience for all crimes, property crime, and violent crime are coded as variety scores. The mean score for all crimes is 3.651 (SD=1.882), for property crime is 1.960 (SD=1.341), and for violent crime is 1.691 (SD=0.825).

Analytic Plan

The current thesis models three outcomes: variety scores for all crimes, property crimes, and violent crimes. The self-reported variety scores are count outcomes. A Poisson regression or negative binomial regression is more appropriate than OLS in testing the model because the use of a linear regression model may lead to inefficient, inconsistent, and biased estimates (Long, 1997). The offending variety score does not follow a normal distribution and a large portion of responses are 0 (50.44%), making the distribution highly right-skewed (Figure 3). Similarly, crime-specific offense variety scores are also not normally distributed (Figure 4 and Figure 5) with many cases of 0 (77.40% for property offenses and 54.51% for violent offenses). There is evidence

of over-dispersion in the variety score distribution for all crimes (M=0.81, SD=1.232) and for property crimes (M=0.267, SD=0.698). Overdispersion is less prominent for violent crimes (M=0.543, SD=0.743).

Figure 3. Distribution of Dependent Variable Offense Variety Score

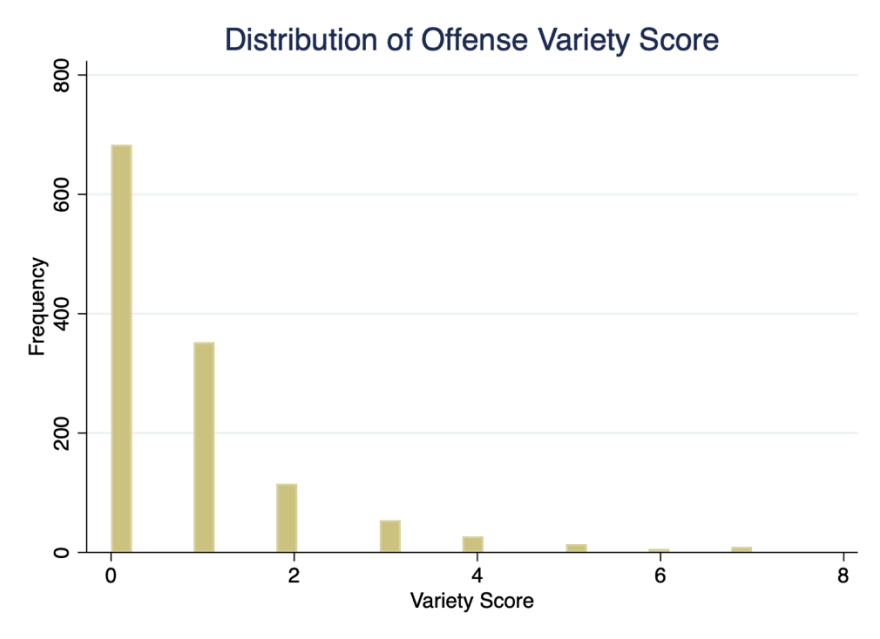


Figure 4. Distribution of Dependent Variable Property Offense Frequency

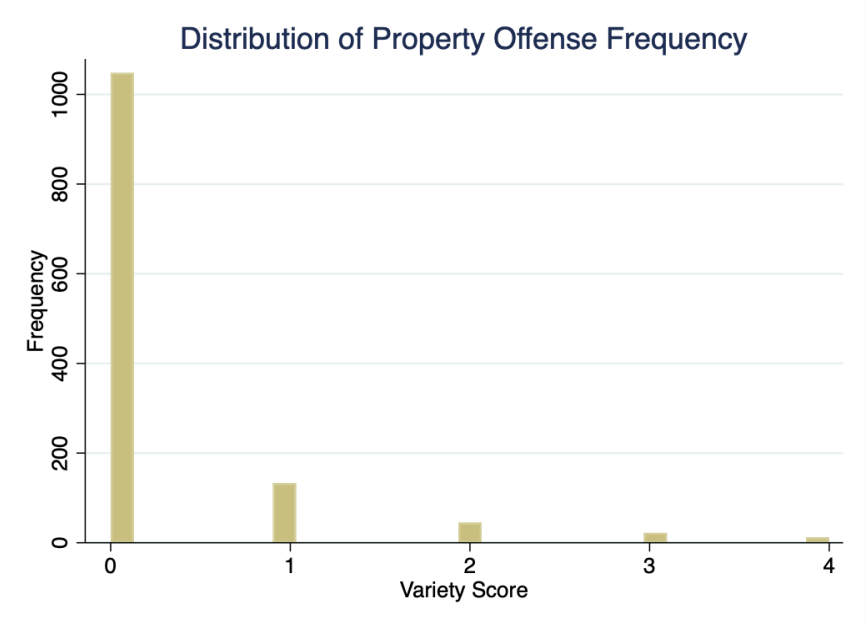
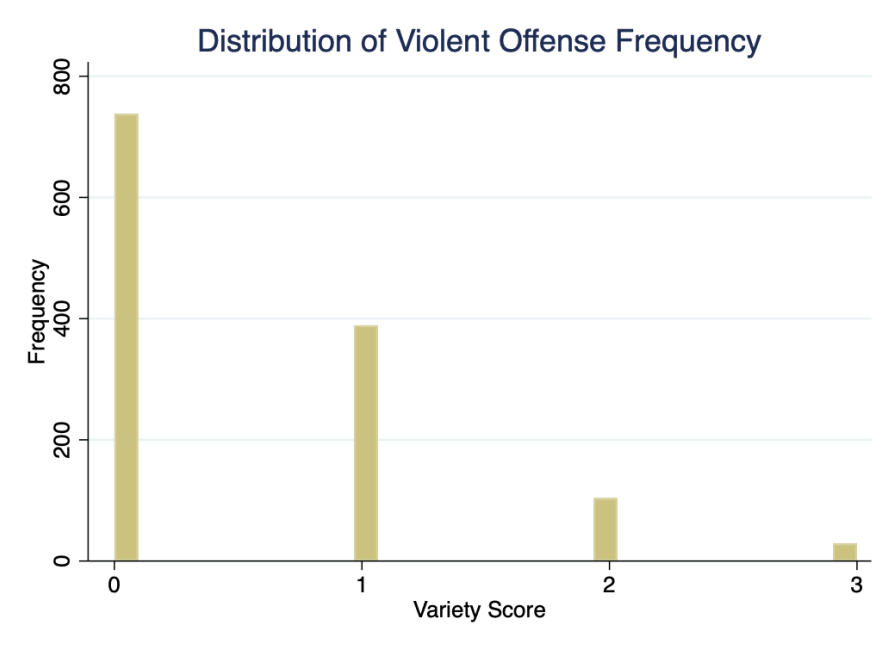


Figure 5. Distribution of Dependent Variable Violent Offense Frequency



As discussed in Berk and MacDonald (2008), there may be two sources from which the observed overdispersion stems. The first is misspecification of the model (i.e., omitted variables) and functional form, and the second is excessive variation in the stochastic component of the model, which the negative binomial regression could potentially solve. Both the Poisson regression and negative binomial regression engage in the same expected mean estimation process, so the resulting coefficient estimates will be very similar (Berk & MacDonald, 2008). Hence, if the systematic portion of the Poisson regression is not correct, the estimates will be biased and inconsistent in both count models. The current thesis has attempted to include relevant factors from previous work and theories, yet it is difficult to parse out whether the excessive variance originates from the systematic or stochastic portion of the model. To stay on the cautious side, the main models first employ a Poisson regression. I first compare the residual deviations from models with and without some key control variables to get a sense of the overdispersion. Subsequent sensitivity tests are conducted using negative binomial regression to examine the robustness of the results.[3]

One important concern that arises is missing values in the data. From the summary table (Table 1), there are missing values across almost all variables. Specifically, the impulsivity (17.38%) and the maternal warmth (13.86%) measures

[3] The plotted residuals from the Poisson regression for all crime and property crime show that the models generally underpredict 0 count and overpredict 1 count, which is reasonable for the overdispersion. However, the predicted values come closer to the observed values (i.e., residuals become smaller) as I slowly add in key independent variables to the model. Although this is not a test to confirm the source of overdispersion, it does suggest that part of the observed overdispersion may come from the specification of the model which negative binomial regression cannot address (Berk & MacDonald, 2008). Therefore, I decide to conduct the main analyses using Poisson regression with negative binomial regression as a robustness check for all crime and property crime. As for violent crimes, the plotted residuals from the Poisson regression closely predicts the observed counts, which confirms that there is less issue of overdispersion in the violent crime variable.

have the most number of missing values. The overall extent of missing cases largely represents a constellation of missing values over many variables rather than one variable being responsible. Using a listwise deletion method that discards any observation with missing values to treat the missing issue would likely result in a loss of approximately 35.38% of data, which can result in inefficient and potentially biased estimates (Allison, 2001). To use single imputation or regression imputation methods, which replaces missing values with mean, median, or predicted values, would underestimate the variance in the model, which can potentially lead to not only biased estimates but also underestimated standard errors (Allison, 2001). I decide to employ multiple imputation chained equations (MICE) to treat missing data on all the variables (Rubin, 1987) using Stata's `mi impute chained` command. Multiple imputation has a couple advantages compared to listwise deletion and single imputation methods. First, it uses simulation-based techniques to generate sets of imputations from predictors that are more accurate than single imputation estimates (Little & Rubin, 2002). Second, results from multiple imputation account for variability of the estimates, which results in more accurate estimation of standard errors (Graham et al., 2007; Little & Rubin, 2002).

Multiple imputation requires the missing data mechanisms to be missing at random (MAR) (Rubin, 1987), which assumes that the probability of missingness may be related to observed factors but not to unobserved factors. To more properly estimate the missing data, I include all non-missing parameters that are correlated with the missing variables. In sum, the imputation step includes all the predictors in the analyses

and estimated over 10 imputations of 20 datasets using a linear function for continuous variables and Poisson function for count variables.

Table 1. Descriptive Statistics before Imputation

Variables	*N*	Mean	SD	Min	Max
Dependent Variable					
Variety Score (All)	1,260	0.810	1.232	0	7
Variety Score (Property)	1,260	0.267	0.698	0	4
Variety Score (Violent)	1,260	0.543	0.743	0	3
Independent Variable					
Physiological Rewards (All)	1,261	2.274	2.491	0	10
Physiological Rewards (Property)	1,261	2.080	2.605	0	10
Physiological Rewards (Violent)	1,261	2.532	2.711	0	10
Impulsivity	1,079	11.73	3.329	5	20
Controls					
Age at Wave 2	1,265	16.55	1.150	14	20
Race					
White	1,306	0.204	0.403	0	1
Black	1,306	0.412	0.492	0	1
Hispanic	1,306	0.337	0.473	0	1
Other	1,306	0.0467	0.211	0	1
Male	1,306	0.864	0.342	0	1
Socioeconomic Status (SES)	1,298	36.57	12.24	11	77
Study Site					
Philadelphia, PA	1,306	0.516	0.500	0	1
Phoenix, AZ	1,306	0.484	0.500	0	1
Peer Delinquency	1,221	1.963	0.875	1	5
Maternal Warmth	1,125	3.191	0.721	1	4
Perceived Risk	1,247	5.194	2.989	0	10
Proportion Time Spent on Street	1,262	0.521	0.439	0	1
Offense History (All)	1,306	3.645	1.870	0	7
Offense History (Property)	1,306	1.958	1.334	0	4
Offense History (Violent)	1,306	1.688	0.821	0	3

Notes: *N* in the table represents the number of individuals.

For analysis, the first set of models evaluates the mediation hypothesis by regressing offense variety score on impulsivity, physiological rewards, and controls. Generalized structural equation modeling (GSEM) in Stata is used because it supports Poisson regressions and most importantly, it can directly estimate indirect associations in the mediation model (Little et al., 2007). The indirect effects of the mediating variable are assessed by the Sobel test, or the product-of-coefficients approach (Preacher & Hayes, 2008). The Sobel test relies on the assumption that the sampling distribution of the mediating effect falls on a standard normal distribution, and violation would result in poor performance and concerns of Type I error (MacKinnon et al., 2002; Preacher & Hayes, 2008). To evaluate the moderation hypothesis, the second set of models include an interaction term of impulsivity and perceived physiological rewards. The mediation and moderation models are also investigated for the two crime-specific offending outcomes (i.e., property crime and violent crime) and reward variables. Robust standard errors are estimated to account for potential violation of the underlying assumptions in the error terms (Tsou, 2006).

Chapter 4: Results

Impulsivity and Rewards

A preliminary inspection into the difference between impulsivity and physiological rewards in the data suggests the two constructs are indeed empirically distinct. First, the correlation between the two measures is relatively low (r=0.24; Appendix B). Second, an exploratory factor analysis on the 5 items of impulsivity and the 7 items of physiological rewards likewise underscores their distinction. Following the Kaiser rule (Nunnally, 1967), the factor analysis results yield two factors of eigenvalues greater than 1. The first factor has an eigenvalue of 4.1675 and consisted of all items from the impulsivity questionnaire which accounted for 0.8487 of the variance. Factor loadings in the first factor range from 0.5747 to 0.8771. All the items from the reward questionnaire load onto factor 2, which has an eigenvalue of 1.1863 and account for further 0.2416 of the variance. Factor loadings in the second factor range from 0.3326 to 0.6129. The results do not change when an oblique rotation is used. Overall, the correlation and exploratory factor analysis support the idea that impulsivity and physiological rewards are conceptually related but are nonetheless different constructs.

Main Analyses

The imputation step is carried out using all observations that had *at least* one variable with non-missing values in wave 2 and 3 because the imputation model cannot estimate values if *all* variables are missing for an observation. There are 48 respondents who did not complete both the wave 2 and wave 3 interviews (i.e., missing on all

variables), therefore the final analytic sample includes 1,306 individuals. The inclusion of the dependent variable in the imputation step is crucial to preserving the relationship between the dependent and independent variables (Johnson & Young, 2011). Without including the dependent variable in the imputation model will attenuate any relationship the independent variables have with the outcome (Graham, 2009; Johnson & Young, 2011). Whether to include imputed values of the dependent variable in the analysis is another set of decisions. One method that includes the dependent variable in the imputation step but later excludes the missing values in the analysis step (i.e., the multiple imputation then deletion, or MID) is suggested when there is high amount of missingness in the dependent variable (von Hippel, 2007). Simulation shows that there is little difference between estimates from MID and that from keeping the imputed values if there is a larger number of imputations and smaller percentage of missing data in the dependent variable (Johnson & Young, 2011; von Hippel, 2007). In this case, the dependent variable, offending variety score, is missing on 3.52% of the values. Therefore, for the current thesis, I decide to keep the imputed values of the dependent variables in the analyses.

Table 2, Table 3, and Table 4 report the Poisson analyses for self-reported offending on all crimes, property crimes, and violent crimes, respectively. Models 1 in the three tables show the relationship between impulsivity and offending with controls included. The direct relationships for impulsivity and physiological rewards on crime are consistent with expectations and are similar across the crime types (i.e., all, violent, and property crimes). For all crimes (Table 2), one standard deviation increase in impulsivity scale is associated with an average 21.0% increase ($b=0.191$, $p<0.001$) in

the offending variety score controlling for other factors. Model 2 (Table 2) indicates that both impulsivity and physiological rewards have significant direct associations with offending, such that a one standard deviation increase in the impulsivity score and perceived physiological rewards is associated with 16.6% ($b=0.154$, $p<0.001$) and 23.0% ($b=0.207$, $p<0.001$) increase in offending, respectively.

For crime-specific analyses, Table 3 reports the Poisson models for property crime. Model 1 shows that a standard deviation increase in impulsivity score is associated with an average 42.2% increase ($b=0.352$, $p<0.001$) in property offenses controlling for other factors. Model 2 reveals that both impulsivity and physiological rewards of property crime have significant direct associations with property offending. A one standard deviation increase in impulsivity score is associated with 32.3% ($b=0.280$, $p<0.001$) increase in property offending and a standard deviation increase in perceived physiological rewards is related to 38.5% ($b=0.326$, $p<0.001$) increase in property offending. For violent crimes, Table 4 shows that both impulsivity alone and violent-specific physiological rewards have significant direct associations with violent offending (Models 1 and 2). A one standard deviation increase in impulsivity score is related to 11.0% ($b=0.104$, $p<0.01$) increase in violent offending and a one standard deviation increase in perceived physiological rewards is related to 16.6% ($b=0.154$, $p<0.001$) increase in violent offending, controlling for other factors.

Across the three offending specifications, I find statistically significant mediation relationships for physiological rewards. From the regression model included in the GSEM mediation estimation for all crimes, impulsivity positively predicts physiological rewards with controls included ($b=0.145$, $se=0.028$, $p<0.001$; not shown

in tables). The indirect effect is tested using the Sobel test. The results in Table 2 indicate partial mediation by physiological rewards (b=0.030, se=0.0081, p<0.001) and the indirect relationship accounts for 16.2% of the total relationship between impulsivity and offending with control variables included. For crime-specific results, impulsivity is positively associated with physiological rewards of property crime (b=0.145, se=0.029, p<0.001; not shown in tables) and violent crime (b=0.123, se=0.030, p<0.001; not shown in tables). For property crime, results from the Sobel test indicate partial mediation by physiological rewards (b=0.047, se=0.013, p<0.001) and the indirect relationship accounts for 14.5% of the total relationship between impulsivity and property offending. Whereas for violent crime, the Sobel test shows partial mediation by violent-specific physiological rewards (b=0.019, se=0.0063, p<0.01) and the indirect relationship accounts for 15.4% of the total association between impulsivity and violent offending.

I also hypothesize that the interaction between impulsivity and rewards will be statistically significant, reflecting that individuals with higher impulsivity weigh physiological reward more than those with lower impulsivity. Model 3 from Table 2 shows that there is not a statistically significant moderating relationship for impulsivity and physiological rewards. Similarly, I find no statistically significant moderating relationship for impulsivity and property-specific physiological rewards (Table 3 Model 3), nor do I find the interaction term between impulsivity and violent-specific physiological rewards to be statistically significant (Table 4 Model 3).

The main analyses also discover relationships from other covariates that are worth mentioning. From Table 2, the association between age and offending is

statistically significant for all three models, suggesting an average lower involvement in offending for older participants. Male participants also have greater variety scores in general, such that males have an average 80% higher variety score than female participants, holding other variables constant. Peer delinquency and perceived risk are both significant predictors of offending. A one-level increase in how much the participant's peers are engaged in antisocial activities is related to an average 35.5% rise in the individual's own offending. A one-level increase in perceived risk of arrest is associated with a 2.93% lower offending variety score (Model 3).

The covariates which are significantly related to the property crime variety score are partially consistent with those from all crimes (Table 3). The association between peer delinquency and property offending has a similar magnitude compared to all crimes (Table 2), with a one-level increase in peer delinquency associated to an average 37.2% increase in property crime engagement. Perceived risk of arrest is only negatively associated with offending in the impulsivity-only model (Model 1), and not statistically significant when perceived rewards are included. The participants in Philadelphia also have an average lower property crime variety score compared to others in Arizona. Unlike the findings from all crimes (Table 2), the age and gender of the participant are not statistically significant predictors of property-specific offending. Moreover, maternal warmth is negatively associated with property offending, such that a one-unit increase in the maternal warmth scale is related to 18.3% lower variety score of property crimes. For violence-related crimes, Table 4 suggests that males on average have 107.9% greater violent offense variety score compared to female participants, and each one-year increase in age is related to about 6.7% decrease in type of violent

offenses engaged. Peer delinquency and perceived risk of arrest are both statistically significant predictors of violent offending.

Table 2. Poisson Models Estimating the Relationship between Impulsivity, Physiological Rewards, and Variety Score for All Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.191***	0.154***	0.140***
	(0.0418)	(0.0419)	(0.0423)
Physiological Rewards	-	0.207***	0.187***
		(0.0405)	(0.0415)
Impulsivity x Rewards	-	-	0.0546
			(0.0383)
Age	-0.0822*	-0.0694*	-0.0685*
	(0.0340)	(0.0333)	(0.0333)
Race/Ethnicity			
White	0.0587	0.0486	0.0508
	(0.194)	(0.196)	(0.195)
Black	-0.0998	-0.0894	-0.0961
	(0.196)	(0.198)	(0.197)
Hispanic	0.00337	-0.000792	-0.00419
	(0.189)	(0.192)	(0.191)
Male	0.659***	0.588***	0.587***
	(0.166)	(0.164)	(0.165)
SES	0.00134	0.000771	0.000860
	(0.00335)	(0.00328)	(0.00327)
Study Site PA	-0.343***	-0.184	-0.169
	(0.102)	(0.104)	(0.105)
Peer Delinquency	0.353***	0.304***	0.303***
	(0.0414)	(0.0412)	(0.0414)
Maternal Warmth	-0.0641	-0.0584	-0.0636
	(0.0577)	(0.0566)	(0.0568)
Proportion Time on Street	7.68e-05	-0.00657	-0.00480
	(0.103)	(0.100)	(0.100)
Perceived Risk	-0.0368*	-0.0288	-0.0297*
	(0.0148)	(0.0148)	(0.0148)
Constant	0.272	0.0836	0.0736
	(0.676)	(0.674)	(0.675)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

Table 3. Poisson Models Estimating the Relationship between Impulsivity, Property-Specific Physiological Rewards, and Variety Score for Property Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.352***	0.280***	0.254**
	(0.0785)	(0.0809)	(0.0870)
Physiological Rewards	-	0.326***	0.299***
		(0.0624)	(0.0694)
Impulsivity x Rewards	-	-	0.0624
			(0.0692)
Age	-0.0954	-0.0672	-0.0665
	(0.0606)	(0.0603)	(0.0602)
Race/Ethnicity			
White	0.552	0.485	0.482
	(0.405)	(0.409)	(0.407)
Black	-0.0617	-0.0882	-0.102
	(0.427)	(0.430)	(0.429)
Hispanic	0.482	0.422	0.415
	(0.400)	(0.403)	(0.401)
Male	0.444	0.344	0.342
	(0.244)	(0.238)	(0.238)
SES	0.00201	0.00122	0.00152
	(0.00564)	(0.00555)	(0.00553)
Study Site PA	-0.678***	-0.439*	-0.419*
	(0.202)	(0.203)	(0.207)
Peer Delinquency	0.386***	0.316***	0.314***
	(0.0711)	(0.0691)	(0.0694)
Maternal Warmth	-0.207*	-0.202*	-0.205*
	(0.0994)	(0.0975)	(0.0978)
Proportion Time on Street	-0.195	-0.190	-0.194
	(0.176)	(0.171)	(0.171)
Perceived Risk	-0.0507*	-0.0390	-0.0401
	(0.0251)	(0.0260)	(0.0259)
Constant	-0.237	-0.646	-0.653
	(1.211)	(1.218)	(1.215)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

Table 4. Poisson Models Estimating the Relationship between Impulsivity, Violent-Specific Physiological Rewards, and Variety Score for Violent Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.126**	0.104**	0.0965*
	(0.0397)	(0.0395)	(0.0403)
Physiological Rewards	-	0.154***	0.142***
		(0.0367)	(0.0383)
Impulsivity x Rewards	-	-	0.0396
			(0.0336)
Age	-0.0734*	-0.0696*	-0.0691*
	(0.0318)	(0.0314)	(0.0315)
Race/Ethnicity			
White	-0.179	-0.161	-0.154
	(0.169)	(0.170)	(0.171)
Black	-0.158	-0.137	-0.137
	(0.173)	(0.174)	(0.174)
Hispanic	-0.215	-0.195	-0.194
	(0.167)	(0.169)	(0.170)
Male	0.785***	0.732***	0.732***
	(0.175)	(0.174)	(0.175)
SES	0.00127	0.000549	0.000548
	(0.00320)	(0.00317)	(0.00318)
Study Site PA	-0.192*	-0.0716	-0.0635
	(0.0951)	(0.0974)	(0.0982)
Peer Delinquency	0.336***	0.300***	0.300***
	(0.0398)	(0.0410)	(0.0409)
Maternal Warmth	0.0198	0.0217	0.0172
	(0.0569)	(0.0562)	(0.0568)
Proportion Time on Street	0.106	0.0918	0.0935
	(0.0928)	(0.0913)	(0.0913)
Perceived Risk	-0.0302*	-0.0239	-0.0243
	(0.0139)	(0.0138)	(0.0138)
Constant	-0.590	-0.630	-0.636
	(0.637)	(0.633)	(0.634)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

Sensitivity Analyses

I conduct a series of sensitivity analyses to check the robustness of the current findings. Following guidance from Berk and MacDonald (2008), because Poisson and negative binomial regressions have the same mean estimation process, the estimated coefficients from both models do not differ substantially. However, negative binomial includes an extra parameter to capture excessive variance (i.e., overdispersion) which can yield a more efficient estimate of the standard error if the overdispersion is stochastic. It is difficult to parse out the source of overdispersion, therefore I employ negative binomial regressions for all crime, property crime, and violent crime as a sensitivity check to account for the potential of overdispersion in the stochastic component of the models.

Overall, the negative binomial models support the robustness of the mediation and lack of significant moderation findings across the crime types. Table 5 displays the negative binomial check for the all crimes analysis. It supports the robustness of the mediation findings ($b=0.030$, $se=0.0084$, $p<0.001$ for indirect effect) but likewise suggests the interaction term is not statistically significant (Model 3). Similarly, negative binomial models (Table 6) confirm the significant mediating relationship for property-specific physiological rewards ($b=0.049$, $se=0.014$, $p<0.001$ for indirect effect, with controls) as well as the lack of statistical significant moderation effect. The negative binomial sensitivity check for violent crime is not presented here in the main text because the models initially had issues with convergence. Moreover, when the models did eventually converge, the standard errors of alpha (i.e., overdispersion parameter) do not estimate. Appendix C reports the negative binomial models of

violent-specific crimes for readers who may be interested, but with standard errors of alpha not estimated.

Table 5. Negative Binomial Models Estimating the Relationship between Impulsivity, Physiological Rewards, and Variety Score for All Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.195***	0.158***	0.150***
	(0.0429)	(0.0429)	(0.0433)
Physiological Rewards	-	0.210***	0.191***
		(0.0427)	(0.0436)
Impulsivity x Rewards	-	-	0.0559
			(0.0395)
Age	-0.0774*	-0.0639	-0.0632
	(0.0342)	(0.0338)	(0.0339)
Race/Ethnicity			
White	0.0653	0.0552	0.0563
	(0.183)	(0.188)	(0.189)
Black	-0.0843	-0.0740	-0.0777
	(0.187)	(0.191)	(0.191)
Hispanic	-0.000239	-0.0226	-0.0263
	(0.177)	(0.183)	(0.183)
Male	0.653***	0.587***	0.585***
	(0.162)	(0.161)	(0.161)
SES	0.00125	0.000424	0.000456
	(0.00331)	(0.00320)	(0.00320)
Study Site PA	-0.310**	-0.165	-0.154
	(0.105)	(0.107)	(0.107)
Peer Delinquency	0.381***	0.323***	0.325***
	(0.0455)	(0.0448)	(0.0447)
Maternal Warmth	-0.0714	-0.0614	-0.0663
	(0.0592)	(0.0579)	(0.0582)
Proportion Time on Street	0.0223	0.0174	0.0235
	(0.102)	(0.100)	(0.100)
Perceived Risk	-0.0316*	-0.0249	-0.0257
	(0.0157)	(0.0155)	(0.0155)
Lnalpha	-0.663***	-0.773***	-0.786***
	(0.153)	(0.166)	(0.167)
Constant	0.106	-0.0641	-0.0775
	(0.676)	(0.673)	(0.676)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

Table 6. Negative Binomial Models Estimating the Relationship between Impulsivity, Property-Specific Physiological Rewards, and Variety Score for Property Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.357***	0.295***	0.275**
	(0.0846)	(0.0856)	(0.0898)
Physiological Rewards	-	0.334***	0.306***
		(0.0657)	(0.0737)
Impulsivity x Rewards	-	-	0.0718
			(0.0771)
Age	-0.0943	-0.0643	-0.0613
	(0.0633)	(0.0648)	(0.0649)
Race/Ethnicity			
White	0.634	0.567	0.565
	(0.375)	(0.392)	(0.394)
Black	0.00561	-0.0308	-0.0407
	(0.403)	(0.417)	(0.420)
Hispanic	0.495	0.387	0.380
	(0.366)	(0.383)	(0.386)
Male	0.436	0.383	0.378
	(0.240)	(0.233)	(0.233)
SES	0.00231	0.000781	0.000814
	(0.00570)	(0.00562)	(0.00561)
Study Site PA	-0.639**	-0.424*	-0.407
	(0.207)	(0.211)	(0.214)
Peer Delinquency	0.452***	0.351***	0.355***
	(0.0815)	(0.0781)	(0.0776)
Maternal Warmth	-0.243*	-0.224*	-0.228*
	(0.103)	(0.101)	(0.101)
Proportion Time on Street	-0.135	-0.115	-0.107
	(0.183)	(0.182)	(0.182)
Perceived Risk	-0.0389	-0.0321	-0.0339
	(0.0278)	(0.0283)	(0.0282)
Lnalpha	0.501**	0.349	0.338
	(0.186)	(0.209)	(0.209)
Constant	-0.450	-0.836	-0.887
	(1.227)	(1.247)	(1.252)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

A second potential concern with the current measures and models is that the sample consists of individuals who had prior contact with the criminal justice system for various types of crime, along with those who may not have such experience. The different offending experiences in the current sample may have two possible influences on the measure of physiological rewards. On the one hand, someone with more extensive offense history may report physiological rewards differently compared to others who may have less experience. On the other hand, reporting of physiological rewards on certain crimes that individuals have experience with may differ compared to other crimes with which they have no prior experience. Given the nature of the dataset, I am unable to disentangle the different influences in the measure. Therefore, as the second form of sensitivity analysis, I include a lagged dependent variable (i.e., offense history) to account for previous experience with crime. Controlling for a lagged dependent variable does not solve the different nuances of how experience can impact reward reporting, but it may provide a first step in parsing out this influence.

Unsurprisingly, prior history of all crimes (Table 7), property offense (Table 8), and violent offense (Table 9) are all statistically significant predictors of offending for the different types of crime when included in the models. However, as Table 7 demonstrates, the inclusion of a lagged DV does not alter the support for the mediation hypothesis ($b=0.018$, $se=0.006$, $p<0.01$ for indirect effect) nor the moderation hypothesis. Table 8 also provide support for the mediation hypothesis ($b=0.035$, $se=0.012$, $p<0.01$ for the indirect effect) but not for the moderating relationship when controlling for property offense history. Likewise, the mediation hypothesis is supported ($b=0.011$, $se=0.0048$, $p<0.05$ for the indirect effect; Table 9) when

controlling for violent offense history, but the moderating relationship remains not significant.

Table 7. Poisson Models Including the Lagged DV - Offense History for All Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.134**	0.112**	0.0964*
	(0.0416)	(0.0418)	(0.0426)
Physiological Rewards	-	0.159***	0.135**
		(0.0396)	(0.0416)
Impulsivity x Rewards	-	-	0.0619
			(0.0369)
Age	-0.0995**	-0.0862**	-0.0849**
	(0.0333)	(0.0327)	(0.0326)
Race/Ethnicity			
White	0.0421	0.0386	0.0422
	(0.194)	(0.195)	(0.193)
Black	-0.0806	-0.0717	-0.0779
	(0.196)	(0.196)	(0.195)
Hispanic	-0.0230	-0.0325	-0.0380
	(0.188)	(0.190)	(0.189)
Male	0.530**	0.483**	0.481**
	(0.164)	(0.163)	(0.164)
SES	0.000541	5.25e-05	0.000125
	(0.00328)	(0.00323)	(0.00322)
Study Site PA	-0.183	-0.0751	-0.0580
	(0.0989)	(0.101)	(0.102)
Peer Delinquency	0.254***	0.224***	0.224***
	(0.0448)	(0.0445)	(0.0443)
Maternal Warmth	-0.0449	-0.0426	-0.0484
	(0.0565)	(0.0556)	(0.0560)
Proportion Time on Street	0.136	0.122	0.124
	(0.102)	(0.0999)	(0.0999)
Perceived Risk	-0.0231	-0.0178	-0.0186
	(0.0149)	(0.0149)	(0.0149)
Offense History	0.185***	0.169***	0.171***
	(0.0244)	(0.0245)	(0.0244)
Constant	-0.106	-0.241	-0.265
	(0.682)	(0.680)	(0.682)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

Table 8. Poisson Models Including the Lagged DV - Offense History for Property Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.292***	0.240**	0.201*
	(0.0803)	(0.0819)	(0.0888)
Physiological Rewards	-	0.280***	0.240***
		(0.0641)	(0.0727)
Impulsivity x Rewards	-	-	0.0873
			(0.0679)
Age	-0.116	-0.0849	-0.0843
	(0.0596)	(0.0598)	(0.0595)
Race/Ethnicity			
White	0.484	0.432	0.428
	(0.413)	(0.414)	(0.411)
Black	0.0138	-0.0156	-0.0331
	(0.432)	(0.432)	(0.430)
Hispanic	0.440	0.374	0.359
	(0.409)	(0.409)	(0.406)
Male	0.295	0.211	0.204
	(0.246)	(0.242)	(0.242)
SES	0.00151	0.000707	0.00107
	(0.00552)	(0.00546)	(0.00543)
Study Site PA	-0.452*	-0.271	-0.239
	(0.193)	(0.193)	(0.197)
Peer Delinquency	0.295***	0.238**	0.238**
	(0.0758)	(0.0730)	(0.0725)
Maternal Warmth	-0.182	-0.180	-0.185
	(0.0956)	(0.0943)	(0.0945)
Proportion Time on Street	-0.0412	-0.0379	-0.0402
	(0.175)	(0.172)	(0.171)
Perceived Risk	-0.0378	-0.0283	-0.0294
	(0.0259)	(0.0267)	(0.0266)
Offense History	0.364***	0.332***	0.339***
	(0.0649)	(0.0669)	(0.0677)
Constant	-0.722	-1.091	-1.113
	(1.236)	(1.243)	(1.237)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

Table 9. Poisson Models Including the Lagged DV - Offense History for Violent Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.0877*	0.0752	0.0681
	(0.0399)	(0.0398)	(0.0408)
Physiological Rewards	-	0.114**	0.103**
		(0.0369)	(0.0386)
Impulsivity x Rewards	-	-	0.0360
			(0.0334)
Age	-0.0864**	-0.0818**	-0.0809**
	(0.0311)	(0.0307)	(0.0308)
Race/Ethnicity			
White	-0.140	-0.126	-0.120
	(0.168)	(0.169)	(0.170)
Black	-0.196	-0.175	-0.174
	(0.171)	(0.172)	(0.172)
Hispanic	-0.228	-0.217	-0.215
	(0.164)	(0.166)	(0.167)
Male	0.700***	0.667***	0.667***
	(0.173)	(0.173)	(0.173)
SES	0.000147	-0.000338	-0.000351
	(0.00316)	(0.00314)	(0.00315)
Study Site PA	-0.130	-0.0459	-0.0390
	(0.0937)	(0.0959)	(0.0966)
Peer Delinquency	0.252***	0.234***	0.234***
	(0.0422)	(0.0425)	(0.0424)
Maternal Warmth	0.0324	0.0329	0.0288
	(0.0563)	(0.0559)	(0.0566)
Proportion Time on Street	0.212*	0.192*	0.193*
	(0.0931)	(0.0923)	(0.0924)
Perceived Risk	-0.0193	-0.0154	-0.0157
	(0.0138)	(0.0137)	(0.0137)
Offense History	0.316***	0.288***	0.288***
	(0.0492)	(0.0500)	(0.0500)
Constant	-0.825	-0.845	-0.856
	(0.639)	(0.636)	(0.638)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses.
*** p<0.001, ** p<0.01, * p<0.05

Chapter 5: Discussion

Prior studies demonstrate that individuals who are more impulsive tend to engage in more delinquency and risk taking (e.g., Lynam & Miller, 2004; Wright et al., 2004). Studies also consistently illustrate a strong association between criminal rewards and offending (e.g., Baker & Piquero, 2010; Loughran et al., 2016; Matsueda et al., 2006). Despite the similarity and overlap in impulsivity and reward processing in the literature, there is considerably little evidence on how rewards "matter" in one's decision to offend. Therefore, the current thesis examines the role of physiological rewards in the impulsivity-offending relationship.

Using data from the Pathways to Desistance study, the analyses reveal that impulsivity and physiological rewards are both positively related to higher engagement in offending variety scores for all crimes, property crime, and violent crime. The direct relationship between rewards and crime is consistent with expectations from rational choice theory and social learning theory, which both assert that criminal rewards are predictive of greater offending (e.g., Hoeben & Thomas, 2019; Loughran et al., 2016). It is also supportive of Katz's (1988) notion that the thrill and rush of crime (i.e., "sneaky thrills") are important, especially for property crimes. Besides rewards, the direct and positive association between impulsivity and offending is in agreement with the general theory of crime (Gottfredson & Hirschi, 1990) as well as numerous other studies (e.g., Lynam & Miller, 2004; Pratt & Cullen, 2000).

I also analyze the mediating role of physiological rewards in order to assess whether individuals with lower or higher impulsivity may perceive rewards differently in a way that invites more offending. Using a GSEM approach, I find support for the

mediation hypothesis that physiological rewards partially explain the relationship between impulsivity and offending, which suggests that individuals with higher levels of impulsivity may on average engage in more offending behaviors at least partly through the anticipation of greater thrill or rush. This is consistent with prior studies that indicate low self-control indirectly shapes offending behavior through physiological rewards (Nagin & Paternoster, 1993) and perceived pleasure of crime (Piquero & Tibbetts, 1996). The mediation analysis in this thesis differs from the earlier works in mainly two ways: one, it examines actual engagement in offending behavior rather than the intention to offend in hypothetical scenarios (i.e., vignettes), and two, it conceptually distinguishes impulsivity from low self-control. As previously discussed, it is important to understand impulsivity and self-control separately as they may have different contributions to offending (Mamayek et al., 2017).

This mediation finding arguably provides support for dual-process theories. If reward expectation for individuals with higher impulsivity are more likely to be influenced by feelings of excitement and heuristics due to a greater reliance of Type I processing (Quartz, 2009), this may suggest that higher impulsivity is associated with greater perception of rewards. Indeed, I find that individuals with higher impulsivity anticipate greater pleasures compared to those who are less impulsive. This also has implications on other criminological theories as well. Rational choice theory and social learning theory are both inherently perceptual, such that the determination of and weight of rewards (and costs) are subjective to the individual decisionmaker. On the other hand, the general theory of crime believes that self-control explains criminal offending (Gottfredson & Hirschi, 1990). The dual-process model provides a

framework to explain how individual attributes like impulsivity can influence the perception (i.e., mediation) of pleasures and pain. The thesis echoes calls made from Nagin and Paternoster (1993) to explore mechanisms in which impulsivity affects choice making as well as suggestions from Mamayek and colleagues (2015) on the use of the dual-process framework to inform theories of both criminal propensity and decision making. It is imperative for subsequent research to further understand different mechanisms through which impulsivity can affect the anticipation of the benefits or costs of crime.

This thesis also hypothesizes that individuals may be differentially sensitive to physiological rewards according to their level of impulsivity. However, the interaction terms between impulsivity and rewards are not statistically significant for the main analysis, nor the crime-specific analyses. Accordingly, I do not find evidence that individuals with varying levels of impulsivity will be differentially susceptible to greater or lower levels of physiological rewards. This is not consistent with the expectations from psychology or behavioral economics (e.g., Ainslie, 1975; Kahneman, 2011; Mamayek et al., 2015). Prior literature alludes to the potential of a moderating relationship between impulsivity and rewards, but few test it with observational data. For instance, using survey data on college students, Sellers (1999) finds a significant negative moderating effect of self-control and rewards on self-reported intimate violence. She concludes that the finding may be due to the types of perceived rewards asked (e.g., social rewards) and the rewards may not be considered immediate to the crime. The thesis mainly differs by using longitudinal data on serious offenders (not students) to assess constructs like impulsivity (not self-control),

physiological rewards (not social or general rewards), and more general offending outcomes (not just courtship aggression).

A potential reason for why a moderation relationship is not found between impulsivity and physiological rewards may be that moderating effects are state-dependent, such that the value of the reward is contingent upon the context which the reward is in. From dual-process theories, Type I thinking may be more prominent when a short-term reward is presented in a situation because Type I processing will produce a quick and intuitive response to the immediate circumstance (Evans, 2003; Evans & Stanovich, 2013). However, asking participants to anticipate how they feel during criminal events may be tapping into Type II decision making because the act requires recall or hypothetical thinking from the participant (Evans, 2012; Evans & Stanovich, 2013). Additionally, it is likely unreasonable to assume that rewards are stable across situations, so it is possible that the current measure of physiological rewards may not be the most ideal to capture what participants actually feel during criminal decision making.

Because it may be possible that the moderating effect of impulsivity and rewards may matter more in context, future studies can use more situational measurements of physiological rewards to better capture immediate rewards associated with the criminal act. Ideally, the measure should assess the value of physiological rewards anticipated immediately prior to the criminal act (i.e., the time of the criminal event decision, Cornish & Clarke, 1986). Prior works on deterrence or rational choice also endorse the use of measures that can better assess perceptions of crime that are situationally-induced or more proximate to the event (Piliavin et al., 1986). The

measure of criminal rewards used in the thesis may be too remote from actual offending to capture the influence of situationally-immediate rewards. Unfortunately, this type of situational measure may be challenging to collect in an actual study. For this reason, vignette studies and scenarios, like the ones used in Nagin and Paternoster (1993) and Piquero and Tibbetts (1996), may provide a closer solution to capturing the situational values of rewards to the extent that the vignettes can elicit feelings of thrill or rush. Another solution suggested by prior works is to provide more context in the questions to capture perceptions of rewards, costs, and risks more specifically (e.g., Piliavin et al., 1986). For example, asking one's perception of rewards in a detailed situation (e.g., specific type of crime, place, time, etc.) rather than in general. One other potential design is using virtual reality to simulate conditions that present physiological rewards (van Gelder et al., 2019). In a virtual reality study, researchers may better capture individual's immediate feelings of thrill or rush for a predesigned criminal event. Overall, it is important for future research to further explore whether impulsivity can influence the preference for physiological reward because the current findings are not significant.

The current measure of physiological rewards may not be ideal for the moderation analysis, but it may be more adequate to study mediation. When respondents are asked about how much thrill or rush they feel in certain crimes, individuals who are more impulsive may tend to report higher thrill possibly because of an automatic Type I response that associates their perception of thrill to crime. This may be similar to the earlier example of the statement "all dogs have a tail," to which the automatic, fast Type I response would be yes (Evans, 2012). This suggests that

individuals may read the rewards question and report their immediate perception of physiological rewards that comes to mind. Therefore, the physiological rewards measure can possibly prompt a Type I response to how people feel about crime, but the measure is insufficient to capture the physiological rewards that are present in the immediate criminal situation, which is more important for the moderation relationship. Future work can attempt to use more detailed version of the current rewards measure and combine it with suggestions discussed earlier (e.g., vignettes, virtual reality) to confirm the mediating and moderating relationship.

In addition, two other factors related to measurement are also worth discussing. From Figure 1 and Figure 2 presented earlier, the distribution of impulsivity and physiological rewards are lower than what prior literature would anticipate. It is possible that social desirability bias, which is the conscious or unconscious tendency to give positive or socially-acceptable answers (Nederhof, 1985), played a role in the responses to these questionnaires. The findings will not be affected substantially if social desirability bias exerts the same influence on all individuals. Yet, if the size of the bias are different for each respondent with no specific pattern, then it introduces more variance in the measurement that can lead to a higher likelihood to find a null result. If there is a pattern where individuals of certain characteristics systematically report lower impulsivity or rewards, then the estimates for the two measures can potentially be biased if those characteristics that influence social desirability are not controlled for in the model. Another factor relates to the length of recall period in the current thesis. Because the average respondent spent half of the recall period on the streets, self-reported offending is only measuring criminal engagement for 3 months

rather than the full 6 months. The shortened recall period can also limit the ability to find statistical significance from capturing fewer criminal occurrences.

Aside from limitations in measurement, there are several other limitations in the current thesis. First, as discussed in a previous section, the thesis is restricted in its ability to generalize beyond the current sample, and the sample is not representative of the broader juvenile offender population nor the general population. Future investigations may be able to benefit from utilizing different samples. One interesting avenue to explore is whether the thesis findings differ for older or younger individuals. For example, whether age can moderate the extent to which more impulsive individuals perceive physiological rewards, and how it relates to offending. In the Pathways data, the average participant at wave 2 is in their late adolescence (i.e., 16.55 years old). Given that adolescence is marked as a period of significant developmental changes in decision making (Albert & Steinberg, 2011), the relationships that physiological rewards have with impulsivity and delinquency in this period may differ compared to those in other age groups. Steinberg (2010) finds that impulsivity and reward-seeking have two different developmental trajectories in adolescents, with impulsivity steadily declining and reward-seeking declining curvilinearly over time. This creates a period during mid-adolescence when individuals have heightened sensation seeking tendency but not enough impulse control, which is hypothesized to lead to more engagement in risky activities. Future work can disentangle this relationship with data that follow individuals from their early adolescence to young adults.

Second, the thesis focuses on the rewarding aspect of crime, hence the perceived risk of arrest is only included as a control variable in the analyses. However,

it is possible that the costs and risks of crime also influence the relationship between impulsivity and offending. Nagin and Paternoster (1993) find that low self-control predicts not only higher perception of criminal rewards but also lower perception of criminal sanctions and shame. On the other hand, Nagin and Paternoster (1994) find that individuals who are more present-oriented and self-interested are on average less likely to be deterred by the perceived risk of crime (i.e., losing one's social capital). Future scholars can explore the complex dynamics of impulsivity, costs, risks, and rewards. For example, it would be fruitful to more fully understand how impulsivity influence perceptions of rewards, costs, and risks under the dual-process model. Consideration of the costs of crime may be more associated with Type II processing because these costs can be more distant in the future. Additionally, future studies can understand how situationally-dependent perceptions of costs, risks, and rewards might differentially relate to offending outcome depending on one's impulsivity.

Third, the analyses illuminate roles that physiological rewards may play in the impulsivity-offending relationship, but the present design could not provide causal conclusions. I attempt to include most of the theoretically relevant variables in the model, but there is still a possibility of omitted variable bias from unobserved factors or other variables that are not included. Although researchers may not be able to manipulate one's impulsivity, future studies can aim to use experimental or quasi-experimental methods to change the scenario or reward presented. For example, studies can match individuals with higher impulsivity to those with lower impulsivity and assess whether the groups' perception of rewards differ for various types of scenarios.

Or, studies can manipulate the amount of immediate rewards presented in a situation and explore whether individuals with varying levels of impulsivity respond differently.

In summary, the current thesis provides a preliminary evaluation of the role that physiological rewards have on impulsivity and offending decision making. I find support for rewards partially mediating the relationship between impulsivity and offending, but I do not find significant moderation effects. This suggests that individuals with higher impulsivity on average perceive greater thrill from crime, yet the physiological rewards do not have a stronger association to crime in those who are more impulsive. From my findings, I propose ways in which dual-process theories and traditional theories of crime can be advanced to better understand offending. For instance, impulsivity and rewards can complement each other in explaining crime. Lastly, the current thesis encourages future scholars to explore the dynamics between individual attributes and perceptual rewards when studying criminal decision making.

Appendices

Appendix A. Measures of the variables used in the thesis

Variable	Definition	Values
Dependent Variable		
Variety Score All Offenses ….	The number of the types of offenses reported in the SRO at wave 3 (12-month interview). The questions asked the participant whether they engaged in the act in the recall period for the following 11 items: (a) destroyed/damaged property (b) entered building to steal (c) shoplifted (d) stolen car/motorcycle (e) shot someone (where bullet hit) (f) shot at someone (pulled trigger) (g) took something by force using weapon (h) took something by force no weapon (i) beaten up somebody badly needed doctor (j) been in a fight (k) broke into car to steal	The variety score ranges from 0 (none) to 7 (committed all types of offenses). A higher score indicates higher self-reported engagement in antisocial or delinquent behaviors in the recall period.

	Crime types (b) and (k) are collapsed, (e) and (f) are collapsed, (g) and (h) are collapsed, (i) and (j) are collapsed.	
Variety Score Property Offenses……	The number of the types of offenses reported in the SRO at wave 3 (12-month interview). The questions asked the participant whether they engaged in the act in the recall period for the following 5 items: (a) destroyed/damaged property (b) entered building to steal (c) shoplifted (d) stolen car/motorcycle (e) broke into car to steal Crime types (b) and (e) are collapsed.	The variety score ranges from 0 (none) to 4 (committed all types of offenses). A higher score indicates higher self-reported engagement in property offenses in the recall period.
Variety Score Violent Offenses……	The number of the types of offenses reported in the SRO at wave 3 (12-month interview). The questions asked the participant whether they engaged in the act in the recall period for the following 6 items: (a) shot someone (where bullet hit) (b) shot at someone (pulled trigger) (c) took something by force using weapon (d) took something by force no weapon (e) beaten up somebody badly needed doctor (f) been in a fight Crime types (a) and (b) are collapsed, (c) and (d) are collapsed, and (e) and (f) are collapsed.	The variety score ranges from 0 (none) to 3 (committed all types of offenses). A higher score indicates higher self-reported engagement in violent offenses in the recall period.
Independent Variables		
Impulsivity (YPI) …….	The YPI impulsivity subscale at wave 2. The subscale is a sum of 5 items:	The original responses were 1 (does not apply at all), 2 (does not apply well), 3 (applied

	(a) I prefer to spend my money right away rather than save it. (b) I consider myself as a pretty impulsive person. (c) It often happens that I talk first and think later. (d) If I get the chance to do something fun, I do it no matter what I had been doing before. (e) If often happens that I do things without thinking ahead.	fairly well), and 4 (applied very well). The subscale ranged from 5-20.
Physiological Rewards ……	Z-score standardized value for physiological rewards scale, which is a mean of 7 items. This is at wave 2. The question asked participants how much thrill or rush it is to do any of the following acts: (a) fighting (b) robbery with a gun (c) stabbing someone (d) breaking into a store or home (e) stealing clothes from a store (f) vandalism (g) auto theft	The original responses were 0 (no fun or kick at all) to 10 (a great deal of fun or kick).
Physiological Rewards (Property)……	Z-score standardized value for physiological rewards scale, which is a mean of 3 items. This is at wave 2. The question asked participants how much thrill or rush it is to do any of the following acts: (a) fighting (b) robbery with a gun (c) stabbing someone	The original responses were 0 (no fun or kick at all) to 10 (a great deal of fun or kick).
Physiological Rewards (Violent)……	Z-score standardized value for physiological rewards scale, which is a mean of 4 items. This is at wave 2. The question asked participants how much thrill or rush it is to do any of the following acts: (a) breaking into a store or home (b) stealing clothes from a store (c) vandalism	The original responses were 0 (no fun or kick at all) to 10 (a great deal of fun or kick).

	(d) auto theft	
Control Variables		
Peer Delinquency ……	Mean of 12 items asking the respondent about their friends' antisocial activities at wave 2: During the recall period, how many of your friends have… (a) purposely damaged or destroyed property that did not belong to them? (b) hit or threatened to hit someone? (c) sold drugs? (d) gotten drunk once in a while? (e) carried a knife? (f) carried a gun? (g) owned a gun? (h) gotten into a physical fight? (i) been hurt in a fight? (j) stolen something worth more than $100? (k) taken a motor vehicle or stolen a car? (l) gone in or tried to go into a building to steal something?	The responses were 1 (none of them), 2 (very few of them), 3 (some of them), 4 (most of them), and 5 (all of them).
Maternal Care …….	Mean of 9 items asking the respondent about their mother's warmth in their relationship at wave 2: When you and your mother have spent time talking or doing things together, how often did your mother… (a) help you do something that was important? (b) let you know she really cares about you? (c) listen carefully to your point of view? (d) act supportive and understanding toward you? (e) act loving or affectionate towards you?	The responses were 1 (never), 2 (sometimes), 3 (often), and 4 (always).

	(f) have a good laugh with you about something that was funny? (g) let you know that she appreciates you, your ideas, or the things you do? (h) tell you she loves you? (i) understand the way you feel about things?	
Perceived Risk of Punishment ……..	The mean of 7 items that asked the participants their perceptions of the certainty of punishment at wave 2. They were asked how likely is it that they will be caught and arrested for the following crimes: (a) fighting (b) robbery with gun (c) stabbing someone (d) breaking into a store or home (e) stealing clothes from a store (f) vandalism (g) auto theft	The original responses were 0 (no chance) to 10 (absolutely certain to be caught).
Proportion of time spent on the streets……	This measure is at wave 2. The proportion of the time (days) during the recall period that the respondent spent outside of facilities without community access, which include: (a) drug/alcohol facility (b) psychiatric facility (c) jail/prison (d) detention center (e) YDC/ADJC (f) contracted residential facilities (general and mental health)	The values range from 0 to 1.
Age ……...	Age of the participant at baseline and at wave 2.	Integer values in years.
Male ……	Dummy variable indicating whether the participant was male.	1 = Male; 0 = Female

Study Site (Philadelphia) ……	Study site location. Dummy variable indicating the study site was Philadelphia, PA.	1 = Philadelphia, PA; 0 = Phoenix, AZ
Race/Ethnicity		
White …….	Dummy variable indicating the participant is White.	1 = White; 0 = Non-White
Black …….	Dummy variable indicating the participant is Black.	1 = Black; 0 = Non-Black
Hispanic ……	Dummy variable indicating the participant is Hispanic.	1 = Hispanic; 0 = Non-Hispanic
Other …….	Dummy variable indicating the participant is neither White, Hispanic, or Black.	1= Other race/ethnicity
Socioeconomic Status (SES)…	Parental index of social position (ISP) at baseline, calculated using mean of mother and father occupation and education score (Hollingshead, 1971): $occupation\ score \times 7 + education\ score \times 4$	Score range from 11-77 with higher scores indicating higher SES.
Offense History …….	Lagged dependent variable. The number of the types of offenses reported in the SRO at wave 1 and 2 (6-month interview) combined. The questions asked the participant whether they have ever engaged in the act and whether they engaged the act in the recall period for the following 11 items. The property offense history variable includes (a), (b), (c), (d), (k), and the violent offense history variable includes (e), (f), (g), (h), (i), (j). (a) destroyed/damaged property (b) entered building to steal (c) shoplifted (d) stolen car/motorcycle (e) shot someone (where bullet hit) (f) shot at someone (pulled trigger) (g) took something by force using weapon	The variety score ranges from 0 to 7 for all offenses, 0 to 4 for property offenses, and 0 to 3 for violent offenses. A higher score indicates higher self-reported history of antisocial or delinquent behaviors.
(Property ……..)		
(Violent ……)		

(h) took something by force no weapon
(i) beaten up somebody badly needed doctor
(j) been in a fight
(k) broke into car to steal
Crime types (b) and (k) are collapsed, (e) and (f) are collapsed, (g) and (h) are collapsed, (i) and (j) are collapsed.

Appendix B.

Table 10. Correlation Matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Variety Score All Crime	1															
2. Physiological Rewards	0.33	1														
3. Impulsivity	0.19	0.24	1													
4. Age	-0.04	-0.02	-0.01	1												
5. White	0.02	0.11	0.11	-0.02	1											
6. Black	-0.13	-0.27	-0.13	0.03	-0.43	1										
7. Hispanic	0.11	0.15	0.03	-0.05	-0.36	-0.61	1									
8. Other Race	0.04	0.08	0.02	0.08	-0.11	-0.18	-0.15	1								
9. Male	0.13	0.13	-0.07	0.02	-0.07	0.03	0.04	-0.02	1							
10. SES	-0.04	-0.04	0.05	0.10	0.24	0.12	-0.35	0.05	-0.05	1						
11. Study Site PA	-0.15	-0.33	-0.14	0.05	-0.27	0.65	-0.40	-0.11	0.04	0.05	1					
12. Peer Delinquency	0.33	0.33	0.25	0.05	-0.04	-0.06	0.09	0.00	0.14	-0.06	-0.02	1				
13. Maternal Warmth	-0.05	-0.15	-0.11	-0.01	-0.10	0.17	-0.09	-0.02	0.08	-0.05	0.19	-0.07	1			
14. Proportion Time on Street	-0.03	0.06	0.00	-0.07	0.16	-0.25	0.11	0.04	-0.20	0.05	-0.31	-0.17	-0.23	1		
15. Perceived Risk	-0.14	-0.11	-0.06	-0.14	0.13	-0.11	0.03	-0.08	-0.16	0.03	-0.17	-0.25	-0.01	0.16	1	
16. Offense History All Crime	0.35	0.37	0.26	0.08	0.04	-0.20	0.16	0.04	0.19	-0.04	-0.21	0.39	-0.06	-0.15	-0.16	1

Appendix C.

Table 11. Negative Binomial Models Estimating the Relationship between Impulsivity, Violent-Specific Physiological Rewards, and Variety Score for Violent Crimes

VARIABLES	Model 1	Model 2	Model 3
Impulsivity	0.126**	0.104**	0.0965*
	(0.0397)	(0.0395)	(0.0403)
Physiological Rewards	-	0.154***	0.142***
		(0.0367)	(0.0383)
Impulsivity x Rewards	-	-	0.0396
			(0.0336)
Age	-0.0734*	-0.0696*	-0.0691*
	(0.0318)	(0.0314)	(0.0315)
Race/Ethnicity			
White	-0.179	-0.161	-0.154
	(0.169)	(0.170)	(0.171)
Black	-0.158	-0.137	-0.137
	(0.173)	(0.174)	(0.174)
Hispanic	-0.215	-0.195	-0.194
	(0.167)	(0.169)	(0.170)
Male	0.785***	0.732***	0.732***
	(0.175)	(0.174)	(0.175)
SES	0.00127	0.000549	0.000548
	(0.00320)	(0.00317)	(0.00318)
Study Site PA	-0.192*	-0.0716	-0.0635
	(0.0951)	(0.0974)	(0.0982)
Peer Delinquency	0.336***	0.300***	0.300***
	(0.0398)	(0.0410)	(0.0409)
Maternal Warmth	0.0198	0.0217	0.0172
	(0.0569)	(0.0562)	(0.0568)
Proportion Time on Street	0.106	0.0918	0.0935
	(0.0928)	(0.0913)	(0.0913)
Perceived Risk	-0.0302*	-0.0239	-0.0243
	(0.0139)	(0.0138)	(0.0138)
lnalpha	-101,524	-54.72	-54.72
	(.)	(.)	(.)
Constant	-0.590	-0.630	-0.636
	(0.637)	(0.633)	(0.634)
Observations	1,306	1,306	1,306

Robust standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05

References

Agnew, R. (2016). A Theory of Crime Resistance and Susceptibility. *Criminology*, *54*(2), 181–211.

Ainslie, G. (1975). Specious reward: A behavioral theory of impulsiveness and impulse control. *Psychological Bulletin*, *82*(4), 463–496.

Akers, R. L. (1985). *Deviant behavior: A social learning approach*. Wadsworth Pub. Co.

Akers, R. L. (1998). *Social learning and social structure: A general theory of crime and deviance*. Northeastern University Press.

Albert, D., & Steinberg, L. (2011). Judgment and Decision Making in Adolescence. *Journal of Research on Adolescence*, *21*(1), 211–224.

Allison, P. D. (2001). *Missing Data*. SAGE Publications.

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (Fifth Edition). American Psychiatric Association.

Anwar, S., & Loughran, T. A. (2011). Testing a Bayesian Learning Theory of Deterrence Among Serious Juvenile Offenders. *Criminology*, *49*(3), 667–698.

Baker, T., & Piquero, A. R. (2010). Assessing the perceived benefits—Criminal offending relationship. *Journal of Criminal Justice*, *38*(5), 981–987.

Bakhshani, N. M. (2014). Impulsivity: A Predisposition Toward Risky Behaviors. *International Journal of High Risk Behaviors & Addiction*, *3*(2).

Baron, S. W. (2003). Self-Control, Social Consequences, and Criminal Behavior: Street Youth and the General Theory of Crime. *Journal of Research in Crime and Delinquency*, *40*(4), 403–425.

Bechara, A., & Damasio, H. (2002). Decision-making and addiction (part I): Impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia*, *40*(10), 1675–1689.

Bechtold, J., Cavanagh, C., Shulman, E. P., & Cauffman, E. (2014). Does Mother Know Best? Adolescent and Mother Reports of Impulsivity and Subsequent Delinquency. *Journal of Youth and Adolescence*, *43*(11), 1903–1913.

Becker, G. S. (1968). Crime and Punishment: An Economic Approach. *Journal of Political Economy*, *76*(2), 169–217. JSTOR.

Berk, R., & MacDonald, J. M. (2008). Overdispersion and Poisson Regression. *Journal of Quantitative Criminology; New York*, *24*(3), 269–284.

Bordua, D. J. (1961). Delinquent Subcultures: Sociological Interpretations of Gang Delinquency. *The ANNALS of the American Academy of Political and Social Science*, *338*(1), 119–136.

Bouchard, S. M., Brown, T. G., & Nadeau, L. (2012). Decision-making capacities and affective reward anticipation in DWI recidivists compared to non-offenders: A preliminary study. *Accident Analysis & Prevention*, *45*, 580–587.

Burgess, R. L., & Akers, R. L. (1966). A Differential Association-Reinforcement Theory of Criminal Behavior. *Social Problems*, *14*(2), 128–147. JSTOR.

Burt, C. H. (2020). Self-Control and Crime: Beyond Gottfredson & Hirschi's Theory. *Annual Review of Criminology*, *3*(1), 43–73.

Burt, C. H., Sweeten, G., & Simons, R. L. (2014). Self-Control Through Emerging Adulthood: Instability, Multidimensionality, and Criminological Significance. *Criminology*, *52*(3), 450–487.

Byck, G. R., Swann, G., Schalet, B., Bolland, J., & Mustanski, B. (2015). Sensation seeking predicting growth in adolescent problem behaviors. *Child Psychiatry and Human Development*, *46*(3), 466–473.

Carmichael, S., & Piquero, A. R. (2004). Sanctions, Perceived Anger, and Criminal Offending. *Journal of Quantitative Criminology*, *20*(4), 371–393.

Carroll, A., Hemingway, F., Bower, J., Ashman, A., Houghton, S., & Durkin, K. (2006). Impulsivity in Juvenile Delinquency: Differences Among Early-Onset, Late-Onset, and Non-Offenders. *Journal of Youth and Adolescence*, *35*(4), 517–527.

Caseras, X., Àvila, C., & Torrubia, R. (2003). The measurement of individual differences in Behavioural Inhibition and Behavioural Activation Systems: A comparison of personality scales. *Personality and Individual Differences*, *34*(6), 999–1013.

Chamberlain, S. R., & Sahakian, B. J. (2007). The neuropsychiatry of impulsivity. *Current Opinion in Psychiatry*, *20*(3), 255–261.

Chudasama, Y. (2011). Animal models of prefrontal-executive function. *Behavioral Neuroscience*, *125*(3), 327–343.

Conger, R. D., Ge, X., Elder, G. H., Lorenz, F. O., & Simons, R. L. (1994). Economic Stress, Coercive Family Process, and Developmental Problems of Adolescents. *Child Development*, *65*(2), 541–561. JSTOR.

Cooper, M. L., Wood, P. K., Orcutt, H. K., & Albino, A. (2003). Personality and the predisposition to engage in risky or problem behaviors during adolescence. *Journal of Personality and Social Psychology*, *84*(2), 390–410.

Cornish, D. B., & Clarke, R. V. (1986). *The Reasoning Criminal: Rational Choice Perspectives on Offending*. Transaction Publishers.

Cressey, D. R. (1960). The Theory of Differential Association: An Introduction Four Articles on Differential Association. *Social Problems*, *8*(1), 2–6.

da Matta, A., Gonçalves, F. L., & Bizarro, L. (2012). Delay discounting: Concepts and measures. *Psychology & Neuroscience*, *5*(2), 135–146.

Dawe, S., Gullo, M. J., & Loxton, N. J. (2004). Reward drive and rash impulsiveness as dimensions of impulsivity: Implications for substance misuse. *Addictive Behaviors*, *29*(7), 1389–1405.

Dawe, S., & Loxton, N. J. (2004). The role of impulsivity in the development of substance use and eating disorders. *Neuroscience & Biobehavioral Reviews*, *28*(3), 343–351.

De Neys, W. (2006). Dual Processing in Reasoning: Two Systems but One Reasoner. *Psychological Science*, *17*(5), 428–433.

De Neys, W., Vartanian, O., & Goel, V. (2008). Smarter Than We Think: When Our Brains Detect That We Are Biased. *Psychological Science*, *19*(5), 483–489.

de Vries, R. E., & van Gelder, J.-L. (2013). Tales of two self-control scales: Relations with Five-Factor and HEXACO traits. *Personality and Individual Differences*, *54*(6), 756–760.

de Wit, H., & Richards, J. B. (2004). Dual Determinants of Drug Use in Humans: Reward and Impulsivity. In *Motivational factors in the etiology of drug abuse. Volume 50 of the Nebraska Symposium on Motivation* (pp. 19–55). University of Nebraska Press.

Dickman, S. J. (1993). Impulsivity and information processing. In *The impulsive client: Theory, research, and treatment* (pp. 151–184). American Psychological Association.

Donohew, L., Zimmerman, R., Cupp, P. S., Novak, S., Colon, S., & Abell, R. (2000). Sensation seeking, impulsive decision-making, and risky sex: Implications for risk-taking and design of interventions. *Personality and Individual Differences*, *28*(6), 1079–1091.

Estle, S. J., Green, L., Myerson, J., & Holt, D. D. (2007). Discounting of Monetary and Directly Consumable Rewards. *Psychological Science*, *18*(1), 58–63.

Evans, J. S. B. T. (2007). *Hypothetical Thinking: Dual Processes in Reasoning and Judgement*. Psychology Press.

Evans, J. S. B. T., & Curtis-Holmes, J. (2005). Rapid responding increases belief bias: Evidence for the dual-process theory of reasoning. *Thinking & Reasoning*, *11*(4), 382–389.

Evans, J. St. B. T. (2003). In two minds: Dual-process accounts of reasoning. *Trends in Cognitive Sciences*, *7*(10), 454–459.

Evans, J. St. B. T. (2012). Dual-Process Theories of Deductive Reasoning: Facts and Fallacies. In K. J. Holyoak & R. G. Morrison (Eds.), *The Oxford handbook of thinking and reasoning* (pp. 115–133). Oxford University Press.

Evans, J. St. B. T., & Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition: Advancing the Debate. *Perspectives on Psychological Science*, *8*(3), 223–241.

Evenden, J. L. (1999). Varieties of impulsivity. *Psychopharmacology*, *146*(4), 348–361.

Eysenck, S. B. G., & Eysenck, H. J. (1977). The place of impulsiveness in a dimensional system of personality description. *British Journal of Social and Clinical Psychology*, *16*(1), 57–68.

Eysenck, Sybil B. G. (1993). The I_7: Development of a measure of impulsivity and its relationship to the superfactors of personality. In *The impulsive client: Theory, research, and treatment* (pp. 141–149). American Psychological Association.

Eysenck, Sybil B. G., & Eysenck, H. J. (1978). Impulsiveness and Venturesomeness: Their Position in a Dimensional System of Personality Description. *Psychological Reports*, *43*(3_suppl), 1247–1255.

Ferrell, J. (1997). Criminological verstehen: Inside the immediacy of crime. *Justice Quarterly*, *14*(1), 3–23.

Forrest, W., Hay, C., Widdowson, A. O., & Rocque, M. (2019). Development of impulsivity and risk-seeking: Implications for the dimensionality and stability of self-control. *Criminology*, *57*(3), 512–543.

Franken, I. H. A., & Muris, P. (2006). Gray's impulsivity dimension: A distinction between Reward Sensitivity versus Rash Impulsiveness. *Personality and Individual Differences*, *40*(7), 1337–1347.

Frederick, S. (2005). Cognitive Reflection and Decision Making. *Journal of Economic Perspectives*, *19*(4), 25–42.

Galván, A. (2013). The Teenage Brain: Sensitivity to Rewards. *Current Directions in Psychological Science*, *22*(2), 88–93.

Gardner, M., & Steinberg, L. (2005). Peer Influence on Risk Taking, Risk Preference, and Risky Decision Making in Adolescence and Adulthood: An Experimental Study. *Developmental Psychology*, *41*(4), 625–635.

Geier, C. F. (2013). Adolescent cognitive control and reward processing: Implications for risk taking and substance use. *Hormones and Behavior*, *64*(2), 333–342.

Geier, C., & Luna, B. (2009). The maturation of incentive processing and cognitive control. *Pharmacology Biochemistry and Behavior*, *93*(3), 212–221.

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic Decision Making. *Annual Review of Psychology*, *62*(1), 451–482.

Gigerenzer, G., & Todd, P. M. (1999). Fast and frugal heuristics: The adaptive toolbox. In *Simple heuristics that make us smart* (pp. 3–34). Oxford University Press.

Goldberg, J. H., Halpern-Felsher, B. L., & Millstein, S. G. (2002). Beyond invulnerability: The importance of benefits in adolescents' decision to drink alcohol. *Health Psychology*, *21*(5), 477–484.

Gottfredson, M. R., & Hirschi, T. (1990). *A general theory of crime*. Stanford University Press.

Graham, J. W. (2009). Missing Data Analysis: Making It Work in the Real World. *Annual Review of Psychology*, *60*(1), 549–576.

Graham, J. W., Olchowski, A. E., & Gilreath, T. D. (2007). How Many Imputations are Really Needed? Some Practical Clarifications of Multiple Imputation Theory. *Prevention Science*, *8*(3), 206–213.

Grasmick, H. G., & Bursik, R. J. (1990). Conscience, Significant Others, and Rational Choice: Extending the Deterrence Model. *Law & Society Review*, *24*(3), 837–861. JSTOR.

Grasmick, H. G., Tittle, C. R., Bursik, R. J., & Arneklev, B. J. (1993). Testing the Core Empirical Implications of Gottfredson and Hirschi's General Theory of Crime. *Journal of Research in Crime and Delinquency*, *30*(1), 5–29.

Green, L., & Myerson, J. (2004). A Discounting Framework for Choice With Delayed and Probabilistic Rewards. *Psychological Bulletin*, *130*(5), 769–792.

Hahn, T., Dresler, T., Ehlis, A.-C., Plichta, M. M., Heinzel, S., Polak, T., Lesch, K.-P., Breuer, F., Jakob, P. M., & Fallgatter, A. J. (2009). Neural response to reward anticipation is modulated by Gray's impulsivity. *NeuroImage*, *46*(4), 1148–1153.

Hariri, A. R., Brown, S. M., Williamson, D. E., Flory, J. D., Wit, H. de, & Manuck, S. B. (2006). Preference for Immediate over Delayed Rewards Is Associated with Magnitude of Ventral Striatal Activity. *Journal of Neuroscience*, *26*(51), 13213–13217.

Haynie, D. L. (2002). Friendship Networks and Delinquency: The Relative Nature of Peer Delinquency. *Journal of Quantitative Criminology*, *18*(2), 99–134.

Hittner, J. B., & Swickert, R. (2006). Sensation seeking and alcohol use: A meta-analytic review. *Addictive Behaviors*, *31*(8), 1383–1401.

Hochstetler, A., DeLisi, M., & Puhrmann, A. M. (2007). Toward an Integrated Model of Offending Frequency: A Replication Study. *Justice Quarterly*, *24*(4), 582–599.

Hoeben, E. M., & Thomas, K. J. (2019). Peers and offender decision-making. *Criminology & Public Policy*, *18*(4), 759–784.

Hoffmann, J. P., & Cerbone, F. G. (1999). Stressful Life Events and Delinquency Escalation in Early Adolescence. *Criminology*, *37*(2), 343–374.

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and Self-Control From a Dual-Systems Perspective. *Perspectives on Psychological Science*, *4*(2), 162–176.

Hollingshead, A.B. (1971). Commentary on The Indiscriminate State of Social Class Measurement. *Social Forces*, *49*(4), 563-567.

Huizinga, D., Esbensen, F.-A., & Weiher, A. W. (1991). Are There Multiple Paths to Delinquency? *The Journal of Criminal Law and Criminology (1973-)*, *82*(1), 83–118. JSTOR.

Johnson, D. R., & Young, R. (2011). Toward Best Practices in Analyzing Datasets with Missing Data: Comparisons and Recommendations. *Journal of Marriage and Family*, *73*(5), 926–945.

Kahneman, D. (2011). *Thinking, Fast and Slow*. Macmillan.

Kahneman, D., & Frederick, S. (2002). Representativeness Revisited: Attribute Substitution in Intuitive Judgment. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.), *Heuristics and Biases* (1st ed., pp. 49–81). Cambridge University Press.

Kalenscher, T., Ohmann, T., & Güntürkün, O. (2006). The neuroscience of impulsive and self-controlled decisions. *International Journal of Psychophysiology*, *62*(2), 203–211.

Katz, J. (1988). *Seductions of crime: Moral and sensual attractions in doing evil*. Basic Books.

Kazemian, L., & Le Blanc, M. (2004). Exploring Patterns of Perpetration of Crime Across the Life Course: Offense and Offender-Based Viewpoints. *Journal of Contemporary Criminal Justice*, *20*(4), 393–415.

Kerr, K. L., Avery, J. A., Barcalow, J. C., Moseman, S. E., Bodurka, J., Bellgowan, P. S. F., & Simmons, W. K. (2015). Trait impulsivity is related to ventral ACC and amygdala activity during primary reward anticipation. *Social Cognitive and Affective Neuroscience*, *10*(1), 36–42.

Kurth-Nelson, Z., Bickel, W., & Redish, A. D. (2012). A theoretical account of cognitive effects in delay discounting. *European Journal of Neuroscience*, *35*(7), 1052–1064.

Little, R. J. A., & Rubin, D. B. (2002). Bayes and Multiple Imputation. In *Statistical Analysis with Missing Data* (pp. 200–220). John Wiley & Sons, Ltd.

Little, T. D., Card, N. A., Bovaird, J. A., Preacher, K. J., & Crandall, C. S. (2007). Structural equation modeling of mediation and moderation with contextual

factors. In *Modeling contextual effects in longitudinal studies* (pp. 207–230). Lawrence Erlbaum Associates Publishers.

Long, J. S. (1997). *Regression Models for Categorical and Limited Dependent Variables*. SAGE.

Loughran, T. A., Paternoster, R., Chalfin, A., & Wilson, T. (2016). Can Rational Choice Be Considered a General Theory of Crime? Evidence from Individual-Level Panel Data. *Criminology*, *54*(1), 86–112.

Loughran, T. A., Pogarsky, G., Piquero, A. R., & Paternoster, R. (2012). Re-Examining the Functional Form of the Certainty Effect in Deterrence Theory. *Justice Quarterly*, *29*(5), 712–741.

Loxton, N. J., Nguyen, D., Casey, L., & Dawe, S. (2008). Reward drive, rash impulsivity and punishment sensitivity in problem gamblers. *Personality and Individual Differences*, *45*(2), 167–173.

Lutz, K., & Widmer, M. (2014). What can the monetary incentive delay task tell us about the neural processing of reward and punishment? *Neuroscience and Neuroeconomics*, *3*, 33-45.

Lynam, D. R. (1996). Early identification of chronic offenders: Who is the fledgling psychopath? *Psychological Bulletin*, *120*(2), 209–234.

Lynam, D. R., Caspi, A., Moffit, T. E., Wikström, P.-O., Loeber, R., & Novak, S. (2000). The interaction between impulsivity and neighborhood context on offending: The effects of impulsivity are stronger in poorer neighborhoods. *Journal of Abnormal Psychology*, *109*(4), 563–574.

Lynam, D. R., & Miller, J. D. (2004). Personality Pathways to Impulsive Behavior and Their Relations to Deviance: Results from Three Samples. *Journal of Quantitative Criminology*, *20*(4), 319–341.

MacKinnon, D. P., Lockwood, C. M., Hoffman, J. M., West, S. G., & Sheets, V. (2002). A Comparison of Methods to Test Mediation and Other Intervening Variable Effects. *Psychological Methods*, *7*(1), 83.

Magid, V., MacLean, M. G., & Colder, C. R. (2007). Differentiating between sensation seeking and impulsivity through their mediated relations with alcohol use and problems. *Addictive Behaviors*, *32*(10), 2046–2061.

Mamayek, C., Loughran, T., & Paternoster, R. (2015). Reason Taking the Reins From Impulsivity: The Promise of Dual-Systems Thinking for Criminology. *Journal of Contemporary Criminal Justice*, *31*(4), 426–448.

Mamayek, C., Paternoster, R., & Loughran, T. A. (2017). Self-Control as Self-Regulation: A Return to Control Theory. *Deviant Behavior*, *38*(8), 895–916.

Mann, F. D., Paul, S., Tackett, J. L., Tucker-Drob, E. M., & Harden, K. P. (2018). Personality Risk for Antisocial Behavior: Testing the Intersections between Callous-Unemotional Traits, Sensation Seeking, and Impulse Control in Adolescence. *Development and Psychopathology*, *30*(1), 267–282.

Marks, L. E. (2011). A Brief History of Sensation and Reward. In J. A. Gottfried (Ed.), *Neurobiology of Sensation and Reward*. CRC Press/Taylor & Francis.

Marquardt, D. W. (1980). A Critique of Some Ridge Regression Methods: Comment. *Journal of the American Statistical Association*, *75*(369), 87–91.

Martin, L. E., & Potts, G. F. (2004). Reward sensitivity in impulsivity. *Neuroreport*, *15*(9), 1519–1522.

Matsueda, R. L., Kreager, D. A., & Huizinga, D. (2006). Deterring Delinquents: A Rational Choice Model of Theft and Violence. *American Sociological Review*, *71*(1), 95–122.

McCarthy, B. (2002). New Economics of Sociological Criminology. *Annual Review of Sociology*, *28*(1), 417–442.

McCarthy, B., & Hagan, J. (2001). When Crime Pays: Capital, Competence, and Criminal Success. *Social Forces*, *79*(3), 1035–1060.

McClure, S. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2004). Separate Neural Systems Value Immediate and Delayed Monetary Rewards. *Science*, *306*(5695), 503–507.

McGloin, J. M., & O'Neill Shermer, L. (2009). Self-Control and Deviant Peer Network Structure. *Journal of Research in Crime and Delinquency*, *46*(1), 35–72.

McGloin, J. M., & Thomas, K. J. (2016). Incentives for Collective Deviance: Group Size and Changes in Perceived Risk, Cost, and Reward. *Criminology*, *54*(3), 459–486.

Miller, E., Joseph, S., & Tudway, J. (2004). Assessing the component structure of four self-report measures of impulsivity. *Personality and Individual Differences*, *37*(2), 349–358.

Moeller, F. G., Barratt, E. S., Dougherty, D. M., Schmitz, J. M., & Swann, A. C. (2001). Psychiatric Aspects of Impulsivity. *American Journal of Psychiatry*, *158*(11), 1783–1793.

Monahan, K. C., Steinberg, L., Cauffman, E., & Mulvey, E. P. (2009). Trajectories of Antisocial Behavior and Psychosocial Maturity From Adolescence to Young Adulthood. *Developmental Psychology*, *45*(6), 1654–1668.

Monterosso, J., & Ainslie, G. (1999). Beyond discounting: Possible experimental models of impulse control. *Psychopharmacology*, *146*(4), 339–347.

Mulvey, E. P., & Schubert, C. A. (2012). Some initial findings and policy implications of the Pathways to Desistance Study. *Victims & Offenders*, *7*(4), 407–427.

Nagin, D. S., & Paternoster, R. (1993). Enduring Individual Differences and Rational Choice Theories of Crime Articles on Culture and Compliance. *Law & Society Review*, *3*, 467–496.

Nagin, D. S., & Paternoster, R. (1994). Personal Capital and Social Control: The Deterrence Implications of a Theory of Individual Differences in Criminal Offending. *Criminology*, *32*(4), 581–606.

Nagin, D. S., & Pogarsky, G. (2003). An Experimental Investigation of Deterrence: Cheating, Self-Serving Bias, and Impulsivity. *Criminology*, *41*(1), 167–194.

Nederhof, A. J. (1985). Methods of coping with social desirability bias: A review. *European Journal of Social Psychology*, *15*(3), 263–280.

Nigg, J. T. (2017). Annual Research Review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control,

impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *58*(4), 361–383.

Nunnally, J. C. (1967). *Psychometric theory*. McGraw-Hill.

O'Donoghue, T., & Rabin, M. (1999). Doing It Now or Later. *The American Economic Review*, *89*(1), 103–124. JSTOR.

O'Donoghue, T., & Rabin, M. (2015). Present Bias: Lessons Learned and To Be Learned. *The American Economic Review*, *105*(5), 273–279. JSTOR.

Paternoster, R., & Pogarsky, G. (2009). Rational Choice, Agency and Thoughtfully Reflective Decision Making: The Short and Long-Term Consequences of Making Good Choices. *Journal of Quantitative Criminology*, *25*(2), 103–127.

Paternoster, R., Pogarsky, G., & Zimmerman, G. (2011). Thoughtfully Reflective Decision Making and the Accumulation of Capital: Bringing Choice Back In. *Journal of Quantitative Criminology*, *27*(1), 1–26.

Patterson, C. M., & Newman, J. P. (1993). Reflectivity and learning from aversive events: Toward a psychological mechanism for the syndromes of disinhibition. *Psychological Review*, *100*(4), 716–736.

Pennycook, G., Neys, W. D., Evans, J. St. B. T., Stanovich, K. E., & Thompson, V. A. (2018). The Mythical Dual-Process Typology. *Trends in Cognitive Sciences*, *22*(8), 667–668.

Peters, J., & Büchel, C. (2010). Neural representations of subjective reward value. *Behavioural Brain Research*, *213*(2), 135–141.

Pfefferbaum, B., & Wood, P. B. (1994). Self-report study of impulsive and delinquent behavior in college students. *Journal of Adolescent Health*, *15*(4), 295–302.

Piliavin, I., Gartner, R., Thornton, C., & Matsueda, R. L. (1986). Crime, Deterrence, and Rational Choice. *American Sociological Review*, *51*(1), 101–119. JSTOR.

Piquero, A., & Tibbetts, S. (1996). Specifying the Direct and Indirect Effects on Low Self-Control and Situational Factors in Offenders Decision Making: Toward a More Comparative Model of Rational Offending. *Justice Quarterly*, *13*(3), 481–510.

Pratt, T. C., & Cullen, F. T. (2000). The Empirical Status of Gottfredson and Hirschi's General Theory of Crime: A Meta-Analysis. *Criminology*, *38*(3), 931–964.

Pratt, T. C., Cullen, F. T., Sellers, C. S., Jr, L. T. W., Madensen, T. D., Daigle, L. E., Fearn, N. E., & Gau, J. M. (2010). The Empirical Status of Social Learning Theory: A Meta-Analysis. *Justice Quarterly*, *27*(6), 765–802.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods*, *40*(3), 879–891.

Quartz, S. R. (2009). Reason, emotion and decision-making: Risk and reward computation with feeling. *Trends in Cognitive Sciences*, *13*(5), 209–215.

Quilty, L. C., & Oakman, J. M. (2004). The assessment of behavioural activation—the relationship between impulsivity and behavioural activation. *Personality and Individual Differences*, *37*(2), 429–442.

Rubin, D. B. (1987). *Multiple imputation for nonresponse in surveys*. Wiley.

Sellers, C. S. (1999). Self-Control and Intimate Violence: An Examination of the Scope and Specification of the General Theory of Crime, *Criminology*, *37*(2), 375–404.

Shulman, E. P., & Cauffman, E. (2013). Reward-Biased Risk Appraisal and Its Relation to Juvenile Versus Adult Crime. *Law and Human Behavior*, *37*(6), 412–423. JSTOR.

Skinner, E. A., & Zimmer-Gembeck, M. J. (2007). The Development of Coping. *Annual Review of Psychology*, *58*(1), 119–144.

Stahl, C., Voss, A., Schmitz, F., Nuszbaum, M., Tüscher, O., Lieb, K., & Klauer, K. C. (2014). Behavioral components of impulsivity. *Journal of Experimental Psychology: General*, *143*(2), 850–886.

Stanovich, K. (2011). *Rationality and the Reflective Mind*. Oxford University Press.

Stanovich, K. E. (1999). *Who is rational? Studies of Individual Differences in Reasoning*. Lawrence Erlbaum Associates.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences*, *23*(5), 645–665.

Steinberg, L. (2010). A dual systems model of adolescent risk-taking. *Developmental Psychobiology*, *52*(3), 216–224.

Steinberg, L., Graham, S., O'Brien, L., Woolard, J., Cauffman, E., & Banich, M. (2009). Age Differences in Future Orientation and Delay Discounting. *Child Development*, *80*(1), 28–44. JSTOR.

Strack, F., & Deutsch, R. (2004). Reflective and Impulsive Determinants of Social Behavior. *Personality and Social Psychology Review*, *8*(3), 220–247.

Sutherland, E. H. (1947). *Principles of criminology, 4th ed*. J. B. Lippincott.

Sweeten, G. (2012). Scaling Criminal Offending. *Journal of Quantitative Criminology*, *28*(3), 533–557.

Thomas, K. J., Loughran, T. A., & Hamilton, B. C. (2020). Perceived arrest risk, psychic rewards, and offense specialization: A partial test of rational choice theory†. *Criminology*, *58*(3), 485-509.

Thomas, K. J., & McGloin, J. M. (2013). A Dual-Systems Approach for Understanding Differential Susceptibility to Processes of Peer Influence. *Criminology*, *51*(2), 435–474.

Thornberry, T. P., Lizotte, A. J., Krohn, M. D., & Farnworth, M. (1994). Delinquent Peers, Beliefs, and Delinquent Behavior: A Longitudinal Test of Interactional Theory. *Criminology*, *1*, 47–84.

Thorndike, E. L. (1911). *Animal intelligence experimental studies,* (Vol. 1–1 online resource (viii, 297 pages) illustrations). Macmillan Co.

Tsou, T.-S. (2006). Robust Poisson regression. *Journal of Statistical Planning and Inference*, *136*(9), 3173–3186.

Tsujii, T., & Watanabe, S. (2009). Neural correlates of dual-task effect on belief-bias syllogistic reasoning: A near-infrared spectroscopy study. *Brain Research*, *1287*, 118–125.

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. *Science*, *185*(4157), 1124–1131. JSTOR.

Tversky, A., & Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, *5*(4), 297–323.

Uggen, C., & Kruttschnitt, C. (1998). Crime in the Breaking: Gender Differences in Desistance. *Law & Society Review*, *32*(2), 339–366.

van Gelder, J. L., & de Vries, R. E. (2012). Traits and States: Integrating Personality and Affect into a Model of Criminal Decision Making. *Criminology*, *50*(3), 637–671.

van Gelder, J. L., & de Vries, R. E. (2014). Rational Misbehavior? Evaluating an Integrated Dual-Process Model of Criminal Decision Making. *Journal of Quantitative Criminology*, *30*(1), 1–27.

van Gelder, J. L., de Vries, R. E., Demetriou, A., van Sintemaartensdijk, I., & Donker, T. (2019). The Virtual Reality Scenario Method: Moving from Imagination to Immersion in Criminal Decision-making Research. *Journal of Research in Crime and Delinquency*, *56*(3), 451–480.

Vitulano, M. L., Fite, P. J., & Rathert, J. L. (2010). Delinquent Peer Influence on Childhood Delinquency: The Moderating Effect of Impulsivity. *Journal of Psychopathology and Behavioral Assessment*, *32*(3), 315–322.

von Hippel, P. T. (2007). Regression with Missing Ys: An Improved Strategy for Analyzing Multiply Imputed Data. *Sociological Methodology*, *37*(1), 83–117.

Warr, M. (2002). *Companions in Crime: The Social Aspects of Criminal Conduct*. Cambridge University Press.

Wason, P. C., & Evans, J. ST. B. T. (1974). Dual processes in reasoning? *Cognition*, *3*(2), 141–154.

White, J. L., Moffitt, T. E., Caspi, A., Bartusch, D. J., Needles, D. J., & Stouthamer-Loeber, M. (1994). Measuring impulsivity and examining its relationship to delinquency. *Journal of Abnormal Psychology*, *103*(2), 192–205.

White, N. M. (2011). Reward: What Is It? How Can It Be Inferred from Behavior? In J. A. Gottfried (Ed.), *Neurobiology of Sensation and Reward*. CRC Press/Taylor & Francis.

Whiteside, S. P., & Lynam, D. R. (2001). The Five Factor Model and impulsivity: Using a structural model of personality to understand impulsivity. *Personality and Individual Differences*, *30*(4), 669–689.

Wills, T. A., Vaccaro, D., & McNamara, G. (1994). Novelty seeking, risk taking, and related constructs as predictors of adolescent substance use: An application of Cloninger's theory. *Journal of Substance Abuse*, *6*(1), 1–20.

Wilson, J. Q., & Herrnstein, R. J. (1985). *Crime and human nature*. Simon and Schuster, Inc.

Wilson, T., Paternoster, R., & Loughran, T. (2017). Direct and Indirect Experiential Effects in an Updating Model of Deterrence: A Research Note. *Journal of Research in Crime and Delinquency*, *54*(1), 63–77.

Wittmann, M., & Paulus, M. P. (2008). Decision making, impulsivity and time perception. *Trends in Cognitive Sciences*, *12*(1), 7–12.

Wright, B. R. E., Caspi, A., Moffitt, T. E., & Paternoster, R. (2004). Does the Perceived Risk of Punishment Deter Criminally Prone Individuals? Rational Choice, Self-Control, and Crime. *Journal of Research in Crime and Delinquency*, *41*(2), 180–213.

Wright, R., & Decker, S. H. (1997). *Armed robbers in action: Stickups and street culture*. Northeastern University Press.

Zimmerman, G. M. (2010). Impulsivity, Offending, and the Neighborhood: Investigating the Person–Context Nexus. *Journal of Quantitative Criminology*, *26*(3), 301–332.

Zuckerman, M. (2010). Sensation Seeking. In *The Corsini Encyclopedia of Psychology* (pp. 1–4). American Cancer Society.